# AN INTRODUCTION

TO THE STUDY OF

# FLOWERLESS PLANTS

THEIR STRUCTURE AND CLASSIFICATION.


BY

ALFRED W. BENNETT, M.A., B.Sc. (Lond.),

VICE-PRESIDENT OF THE LINNEAN SOCIETY;

LECTURER ON BOTANY AT ST. THOMAS'S HOSPITAL;

AUTHOR OF

'A HANDBOOK OF CRYPTOGAMIC BOTANY.'


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# PREFACE.

The function of the National Home Reading Union is to enable students who seek to educate themselves without the assistance of aural teaching and laboratory appliances to reap the greatest benefit possible from reading. With this end in view Committees of the Union, after consulting with the most competent specialists in the country (whose help has been given them hitherto without stint), draw up lists of books suitable for consecutive courses of study. In the first place, however, it is necessary to decide upon a curriculum; this done, the books in the market are arranged along its lines. Probably it is the first time that such an attempt has been made on a large scale by a body entirely independent of publishing interests, and it is, to the Managers of the Union, a surprise to find how inadequate is the supply of books when looked at from this point of view; for while in every department of study certain popular sections are covered by an embarrassing provision of literature, it is equally true that the literature of almost every subject exhibits most remarkable gaps. In the Organic Nature Course the inadequacy of the books was perhaps more marked than in the more distinctly literary subjects. The plan of work, drawn up before publishers' lists had been ransacked, had been arranged to extend over four years. It comprised, during the first year Elementary Biology; in the second year our investigations were carried somewhat more deeply into the Natural History and Anatomy of Animals and Flowering Plants. The work of the ensuing (the third) year will be devoted to Flowerless Plants. The conditions of work in the Science Courses are somewhat different to those which obtain in the other departments of knowledge, for in Science information can be obtained at first hand

from Nature herself, and students have relied hitherto upon the personal direction of a teacher rather than on books. Such is probably the explanation of the great difficulty which the Council of the Home Reading Union have found in selecting books for the Course in Organic Nature. In Elementary Biology the "required book" was made up in the main of the articles by Dr. Hickson and Mr. Francis Darwin which were published as supplements to our magazine. The further studies in Natural History were taken from parts of several books, reinforced and explained in articles by the above-named writers. In Cryptogamic Botany no systematic work of suitable style and price was to be found, and the Union is much indebted to Messrs. Gurney and Jackson for meeting its needs by issuing this section of Henfrey's most excellent text-book as a separate volume. Our thanks are also due to Mr. Bennett, for writing such an introduction as is needed to render this little book independent.

It should be mentioned that the section on Fungi in the edition of Henfrey's 'Elementary Course of Botany,' which forms the groundwork for the present volume, was the work of Mr. Geo. Murray, the joint author, with Mr. Bennett, of the 'Handbook of Cryptogamic Botany.'

ALEX HILL,
*(Chairman of the Executive Committee of the N.H.R.U.)*

Downing College,
August 1891.

# FLOWERLESS PLANTS.

The study of Flowerless Plants or Cryptogams has, during recent years, attracted increasing attention both from amateurs and from more scientific investigators. Many of them, such as Ferns and some species of *Selaginella*, have long been favourite objects of cultivation; others, as for example Mosses, Seaweeds, and the smaller Fungi, are eagerly sought after by collectors; while all present objects of great interest and beauty under the microscope.

What do we mean by a Flowerless Plant? In order to answer this question, we must call to mind the part taken by the flower in the reproduction of ordinary Flowering Plants or Phanerogams. The essential parts of the flower are the pistil and the stamens—the female and the male organs respectively—all the rest playing only a subsidiary part in the process of fertilization. This process consists in the emission by the pollen-grain, after its deposition on the stigma, of a pollen-tube, which penetrates the tissue of the stigma and style, enters the ovary, and fertilizes the ovule by coming into contact with a minute mass of protoplasm known as the oosphere, contained within the embryo-sac. The conspicuous and brightly-coloured parts of the flower are not, however, as a general rule, the pistil and the stamens, but usually the corolla (less often the calyx), the object gained by the bright colour or sweet scent being the attraction of insects for the purpose of assisting in the process of pollination—that is, the deposition of the pollen-grains upon the stigma, without which they could not put out their pollen-tubes in a position to reach and fertilize the ovules. It is true that a considerable number of flowers are altogether inconspicuous, having no scent and either no corolla or a very insignificant one. In these cases the pollen-grains are deposited on the stigma by some other agency than that of insects, and there is therefore no necessity for the flower to be seen from a distance. But, whatever the contrivances for the carriage of the pollen-grains to the stigma, throughout the whole range of Flowering Plants—with the exception of the comparatively small

class known as Gymnosperms, of which the fir-tribe may be taken as a type—the actual process of the fertilization of the ovule is identical in every important point.

In Flowerless Plants or Cryptogams the case is very different; and the first thing which the student has to realize is the enormously greater variation of structure found within the lower than within the higher forms of vegetable life. Instead of Phanerogams and Cryptogams being two divisions of equal rank in the vegetable kingdom, the former are but the highest class (or rather the Angiosperms and Gymnosperms must be regarded as two classes) of a similar rank to the numerous equivalent classes into which the latter may be divided. Indeed the highest Flowerless Plants are much more nearly related to Flowering Plants than they are to the lower Phanerogams; and are hence constantly included in local phanerogamic floras.

In the highest class of Flowerless Plants, that known as "Vascular Cryptogams," there is a "sexual" mode of reproduction strictly analogous to that which takes place in Phanerogams. The "female" element is here also known as the *oosphere*, and is, as in Flowering Plants, a minute naked mass of protoplasm—*i. e.*, it is not clothed with a cell-wall of cellulose; but, instead of being found within an "embryo-sac," and that again enclosed within the ovule, it is contained in the lower part of an organ known as the *archegone* (see fig. 7, p. 26). These organs are found on a structure known as the *prothallium*, and each consists of a papilla-like or conical elevation composed of a considerable number of cells, and having in its "ventral" or lower portion one cell much larger than all the rest called the *central cell*, within which is the oosphere. When the archegone is mature a row of cells immediately above the central cell disappears by deliquescence, often accompanied by the expulsion of a drop of mucilage, and an open *canal* is thus formed, by means of which the central cell is in communication with the outer air through an opening at the summit of the archegone. The "male" organs differ altogether from those of Flowering Plants. They are known as *antherids* (see fig. 6, p. 26), and are also minute conical or hemispherical projections from the prothallium, either the same or a different one from that which produces archegones; or, in the case of the "heterosporous" Vascular Cryptogams, are produced independently of a fully-formed prothallium. The antherid consists of a number of cells, from each of which, when the organ is mature, the contents escape in the form of an *antherozoid* or spermatozoid, a minute mass of protoplasm, coiled in the manner of a corkscrew, to which are attached a number of *vibratile cilia* or flagella, excessively delicate threads of protoplasm, which are always in

rapid oscillating motion, causing the antherozoid to be driven about with great rapidity in the moisture which always clothes the surface of the prothallium. One or more of these antherozoids, entering the open mouth of the archegone, find their way down the canal to the central cell, and, becoming absorbed into the oosphere, fertilize it. The sexual organs in Vascular Cryptogams are always minute microscopic bodies; and, since the antherozoids are conducted to the oosphere by their own power of motion, no external agency is required to bring about fertilization, and there is no need for the compound and conspicuous structure known as the flower. In some Mosses, however, the leaves surrounding the organs of reproduction are more or less modified or coloured, and the structure thus formed is sometimes described as the "flower" of the moss *. The phenomena of reproduction in the small group of Flowering Plants already referred to under the name of Gymnosperms present a most interesting stage of transition between those of the larger group of Flowering Plants or Angiosperms and those of Vascular Cryptogams.

A mode of sexual reproduction resembling in its most important features that described above—the fertilization of a passive female oosphere by an active male antherozoid—is characteristic not only of Vascular Cryptogams, but also of many of the lower forms of Flowerless Plants. In the lowest forms of all, to which special reference will hereafter be made, no mode of sexual reproduction is known; but some families of Cryptogams are characterized by an exceedingly interesting process—known under the general name of *conjugation*—in which the two uniting bodies, known as *gametes*, are to all appearance alike, or are distinguished from one another by only very inconsiderable differences. This process of conjugation is of two distinct kinds. According to one mode, the conjugating cells are stationary (in the same or in different filaments), and one of them puts out a tube through which the contents of that cell pass into the other of the two conjugating cells, commingling with it, and producing a body known as a *zygosperm*, which sooner or later clothes itself with a cell-wall, and has then the faculty of developing into a new plant. We have here what may perhaps be regarded as a process foreshadowing the emission of the pollen-tubes by the pollen-grains of Flowering Plants. In the other mode the two conjugating bodies are masses of protoplasm not enclosed in cellulose, and

* The exact relationships or homologies between the male and female organs of Vascular Cryptogams and those of Phanerogams are discussed at length in Bennett and Murray's 'Handbook of Cryptogamic Botany'; where also the various points of structure of the different groups will be found described much more in detail than is possible in the present volume.

each provided with usually a pair of vibratile cilia, by means of which they are driven about rapidly in moisture, in a manner similar to that of the antherozoids of the higher Cryptogams. When two of these "swarm-spores" or *zoogametes* meet, they fuse together, gradually losing their cilia; and the resulting zygosperm clothes itself in the same way with a coat of cellulose, and develops into a new individual after a period of rest. In certain sea-weeds belonging to the genera *Ectocarpus*, *Cutleria*, and *Dictyota*, there is an exceedingly instructive gradation of phenomena between the conjugation of similar zoogametes and the fertilization of a stationary oosphere by a motile antherozoid. In the first stage a large number of "swarm-spores" are produced, some of which, after a short period of "swarming," become fixed to a solid substance; the two vibratile cilia gradually disappear; and these stationary bodies then appear to exercise an attractive force on other swarm-spores which become absorbed into them, and the female body, thus fertilized, then clothes itself with a cell-wall, and develops, in the ordinary way, into a new individual. In the next stage the female and male elements are both biciliated masses of protoplasm, but the former are many times larger than the latter, and entirely lose their cilia before they are fertilized by them. In the most advanced stage the female reproductive bodies are from the first motionless non-ciliated masses of protoplasm. It is a fair inference from these facts that the primitive and simplest mode of "sexual" reproduction is the coalescence of two equivalent motile "swarm-spores," and that from this has been gradually evolved the process found in all the higher Cryptogams, of the fertilization of a comparatively large motionless oosphere by a minute motile antherozoid.

In addition to the sexual mode of reproduction, both Flowering and Flowerless Plants are multiplied in a variety of non-sexual modes; that is, by the separation of a portion of the parent individual, in which a special store of food-material is often laid up, and its development into an independent plant. By most physiologists this is regarded, not as the production of a new individual, but as the prolongation of the life of a portion of the old individual; and these various modes of non-sexual multiplication are known as *propagation*, in contradistinction to sexual "reproduction." To this category belong the various modes of multiplication in use by gardeners and fruit-growers for perpetuating particular varieties or strains, such as striking, layering, budding, grafting, &c., as well as the natural or artificial propagation by bulbs, tubers, bulbils, &c. Among Flowering Plants these modes of propagation are almost entirely confined to perennial species, annual plants being almost invariably multiplied only by seed.

Among Cryptogams this rule does not in any way hold good, not only the larger and more permanent, but the smallest and most fugitive species being constantly or even habitually multiplied in a non-sexual or vegetative manner. Moreover, as a general rule, the lower you descend in the scale the more do the non-sexual preponderate over the sexual modes of multiplication, until, in the most lowly organized forms of vegetable life, all sexual modes of reproduction are entirely suppressed.

In the higher Flowerless Plants—the Vascular Cryptogams, Muscineæ, and Characeæ—modes of vegetative multiplication are known similar to those which occur in Flowering Plants, by bulbs, bulbils, stolons, &c., which sometimes become detached before germinating, sometimes develop while still attached to the parent plant. Familiar examples of the latter phenomenon are presented by the so-called "viviparous" ferns, several species of which are grown in greenhouses, *Cystopteris bulbifera*, *Asplenium bulbiferum*, &c., the mode of multiplication of which reminds one somewhat of that of the strawberry by runners. Of a somewhat similar nature are the *sclerotes* of some of the larger Fungi. But the characteristic mode of non-sexual propagation in Cryptogams—occurring throughout the whole domain with the exception of a few isolated families, as the Characeæ, the Fucaceæ, and the Conjugatæ— is one entirely unknown in Phanerogams, propagation by *spores*.

The term "spore" has been employed in very different senses by different writers; and the use of it by some has been deplorably lax. In the present treatise its use—and that of all other terms compounded from it—will be limited, in accordance with the definition in Bennett and Murray's 'Handbook of Cryptogamic Botany,' to express any single cell detached from the parent plant for the purpose of vegetative propagation. It will be seen from this definition that the spore is not in any sense the representative or homologue of the seed of Flowering Plants. Its structure, when it is quiescent and non-motile, resembles in many respects that of a pollen-grain. It is a minute microscopic cell, globular, ellipsoidal, or kidney-shaped, containing protoplasm and a nucleus, and clothed with a double cell-wall consisting of two separable layers—an inner *endospore* composed of cellulose, and an outer cuticularized *exospore*, which is often brown, and furnished with conical or wart-like elevations. On germinating, the endospore bursts through the exospore in the form of a germ-tube or *germinating filament*, which either reproduces directly a new plant like the parent plant, or gives birth to a *prothallium* in the case of Vascular Cryptogams, or a *protoneme* in the case of Muscineæ, as will be described in the sequel. Spores of this description—either of one kind only, or of two kinds—larger *megaspores* and smaller *micro-*

*spores*—are the only ones known in the higher Cryptogams, and they occur also in many of the lower families: but by far the most common mode of non-sexual propagation throughout the immense region of the lower Cryptogams is by means of motile ciliated *zoospores*.

A *zoospore* differs from the non-motile spores already described in two important points:—it is a naked mass of protoplasm, not enclosed in a cell-wall of cellulose; and it is provided with *vibratile cilia*, exceedingly delicate threads of protoplasm, by which it is driven about in moisture with great rapidity; the zoospores of most Algæ are coloured green by chlorophyll. These cilia or flagella are usually two in number, both springing from the narrower end of the pear-shaped zoospore; or less often there are four, or a much larger number forming a complete fringe round the spore. It will be seen from this description that zoospores bear a strong resemblance to antherozoids, and a still closer resemblance to zoogametes which coalesce with one another in the act of conjugation. Indeed they are often indistinguishable from the latter except by their larger size; many families of Algæ producing both kinds of "swarm-spore"—larger zoospores which germinate directly, and smaller zoogametes which conjugate to produce a zoosperm. In some cases it would appear as if these motile masses of protoplasm could be made to perform either function under different conditions; and it is a hypothesis in favour of which many facts can be adduced that direct germination is an earlier, germination only after conjugation a later acquired, function of organs originally alike.

In the structure of their tissues Cryptogams present an almost infinite variety. The tissue of Vascular Cryptogams is, in all essential respects, as complicated, and the vegetative organs as strongly differentiated, as those of Flowering Plants. We have a distinct root, stem, and leaves, a differentiated epiderm, fundamental tissue, and vascular bundles, though the latter term is applied with some laxity of use, the "vascular" bundles of Cryptogams resembling those of Gymnosperms rather than those of Angiosperms, inasmuch as their constituent elements are not, strictly speaking, "vessels" resulting from the coalescence of a number of cells, but *tracheids*, greatly enlarged cells. The prevalent form of marking is the *scalariform*, though others occur. This fact is of some historical interest, since it is one of the points of evidence proving that the arborescent vegetation of the globe during the Devonian and Carboniferous periods consisted chiefly of gigantic plants allied to our Equisetaceæ, Lycopodiaceæ, and other families of Vascular Cryptogams, together with some Gymnosperms. In the higher Muscineæ, there still remains a rudimentary indication

of the differentiation of tissues alluded to above; but in the lowest section of Cryptogams, the Thallophytes, this has entirely disappeared, except in some of the highest Algæ. The entire organism here consists of a *thallus* or collection of cells, arranged in one or more filaments or *hyphæ*; but in the larger and more enduring forms these hyphæ are closely packed together, producing a structure with the semblance of a true tissue known as a *pseudo-parenchyme*; but the separate hyphæ of which it is composed can always be isolated by the use of proper means. In a large number of families both of Algæ and Fungi, the entire organism consists of a single branched or unbranched hypha; while in others, and in the whole of the Protophytes, we reach the lowest possible type of organism, *unicellular* plants, each individual consisting of only a single cell. It is here that the boundary-line between the Vegetable and Animal kingdoms becomes indistinct.

In the case of a large number of Cryptogams—all Vascular Cryptogams, most Muscineæ, the Characeæ, and the larger Fungi and Marine Algæ—the distinctions between the genera and species are founded on characters visible to the naked eye, and the various species are as readily distinguished as is the case with Flowering Plants: but with the smaller Fungi, the freshwater Algæ, and all Protophytes, this discrimination requires the use of the microscope. In all cases, except in the Characeæ, the organs of sexual reproduction are microscopic, as also are nearly all the most beautiful points of structure. Among the more interesting and attractive objects for microscopic examination furnished by this division of the vegetable kingdom may be mentioned the following: The spores and sporanges of Ferns; the peristome or ring of teeth surrounding the mouth of the sporange in many Mosses, and the leaves of the Sphagnaceæ or Bog-mosses; in the Characeæ the circulation of protoplasm in the cells and the structure of the archegones and antherids; among Algæ and Protophytes, the beautiful arrangement of the chlorophyll and the process of conjugation in *Spirogyra*, *Zygnema*, and other Conjugatæ, the endless variety of symmetrical forms in the Desmids, the exquisite beauty of the markings on the siliceous coat of Diatoms, the beautiful symmetry of the arrangement of the branches in *Batrachospermum* and *Draparnaldia*, the perfection of form and activity of motion of such organisms as *Volvox*, *Pandorina*, &c., &c.

# CLASSIFICATION

## OF

# FLOWERLESS PLANTS.

THERE is a very different amount of difficulty attending the classification of the upper and of the lower divisions of Cryptogams. In all the higher families the life-history is as well-known, and has been as carefully worked out, as is the case with Flowering Plants; and, except in some minor points of detail, all authorities are agreed as to the lines on which their classification should be

Fig. 1


Simple cellular plants.
A. Yeast-plant vegetating. C. *Penicillium glaucum.*
B. *Aspergillus glaucus.* D. *Mucor Mucedo.*
Multiplied 200 diameters.

carried out. But with the lower forms the case is very different. Not only is the complete cycle of development of many at present but very imperfectly known, but a number of species present so

remarkable a polymorphism—*i. e.*, assume such very different forms under different circumstances—as to suggest the possibility that many species placed at present even in different families may be but different conditions of the same species. This is especially the case with the group of organisms which at present make up the class of Protophytes.

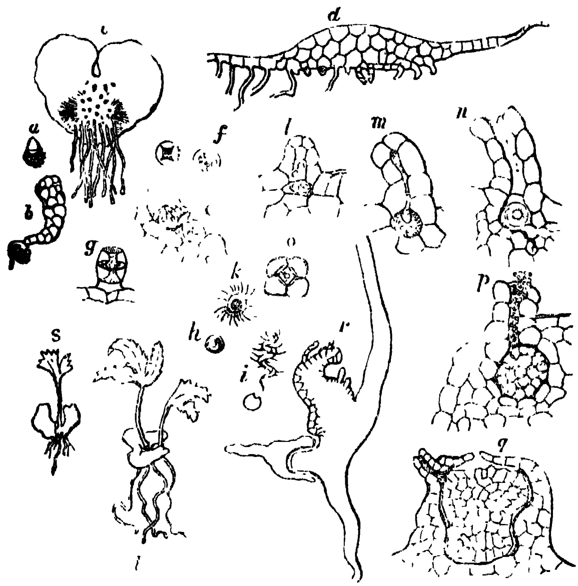
It is convenient to divide Cryptogams into two great groups characterized by differences in the structure of their vegetative organs, although this classification is certainly not a natural one, since it cuts through the well-defined family of Hepaticæ. The higher group, called *Cormophytes*—composed of Ferns and their allies, with the Mosses and most of their allies, and the Characeæ—resemble Phanerogams in the possession of an axis or stem bearing appendicular organs or leaves. The lower group or *Thallophytes*, comprising some of the allies of Mosses, all Algæ and Fungi (including Lichens), and Protophytes, presents in its vegetative structure no clearly marked distinction between root, stem, and leaf; the plant is composed of a thallus, formed of simple cellular tissue, sometimes in its general appearance resembling a leaf, but often of some totally different form. The simplest plants of this class are unicellular (fig. 1). The following are the classes into which these two groups of Cormophytes and Thallophytes are again divided :—

**Cormophytes.**—The two groups of which Cormophytes are composed are distinguished from each other by the structure of their tissues. The Ferns and their allies possess a well-developed vascular system, and, under the name of VASCULAR CRYPTOGAMS, are further divided into the *Selaginellaceæ*, *Rhizocarpeæ*, *Equisetaceæ*, *Filices*, and *Lycopodiaceæ*. The Mosses or *Musci* and their allies the *Hepaticæ* (forming together the class called MUSCINEÆ) possess no true vascular system, though the tissues in the stems and leaves of Mosses have indications of vascular bundles of the most rudimentary kind. In neither Mosses nor Hepatics do true roots, in a morphological sense, occur, though they possess organs (*rhizoids*) which discharge similar functions,

In their life-history VASCULAR CRYPTOGAMS pass through two morphologically and physiologically distinct generations—a sexual or *oophore* stage, and a non-sexual or *sporophore* stage. The *spore*, a propagative organ not the result of impregnation, is borne in various ways in different families; in the Ferns in capsules or *sporanges* usually placed on the back of the frond. On germination the spore produces a thalloid layer of cells called the *prothallium*, and it is on this that the sexual organs are formed. The prothallium contains chlorophyll, and forms numerous rhizoids. It is soon in a position to nourish itself, and produces

the male (*antherids*) and female organs (*archegones*) (see fig. 2). The antherids give rise to *antherozoids* or spermatozoids, which fertilize the archegones. This is the *sexual generation* or oophore.

Fig. 2.




Reproduction of Ferns:—*a*, spore germinating; *b*, more advanced (magn. 50 diam.); *c*, full-grown prothallium, with archegones (lower surface); *d*, vertical section of the central region of a prothallium, passing through an archegone and two antherids; *e*, two antherids (side view); *f*, antherids seen from above; *g*, antherid burst (side view); *h*, mother-cell of antherozoid; *i*, antherozoid escaping from mother-cell (magn. 300 diam.); *k*, front view of an antherozoid; *l*, vertical section of a young archegone, *m*, more advanced; *n*, still older, with the canal open and an oosphere in its ventral portion (magn. 100 diam.); *o*, view of the mouth of an archegone, from above; *p*, vertical section of an archegone with the embryo in course of development; *q*, the same, more advanced (less magnified); *r*, vertical section of young plant, more advanced, with a fragment of the prothallium (magn. 50 diam.); *s*, *t*, young plants of *Pteris serrulata*, with their first and second leaves and adventitious roots still connected with their prothallia.

Out of the fertilized archegone springs the *non-sexual* leaf-bearing generation or sporophore, which, in common language, is usually called a Fern, a Horsetail, &c. It bears the spores, as described, and these in their turn again produce the sexual generation (prothallium), and thus the life-history proceeds in alternate sexual and non-sexual generations. The non-sexual plants possess a vascular system, differing only in details from that of Phanerogams; and a more special description of their structure will be found under

the headings to which they are referred. Their apical growth usually proceeds from a single terminal cell.

In the MUSCINEÆ the alternation of generations differs in the following way from that in Vascular Cryptogams. Out of the germinating spore (in all Mosses and in some *Hepaticæ*) comes a *protoneme* of a thread-like structure, from which springs, by lateral budding, the Moss-plant with its stem and leaves (but a thalloid structure in one section of *Hepaticæ*). The non-sexual generation consists of the *sporogone* only, containing the spores. There are, besides, different modes of vegetative reproduction in Mosses, the principal of which are by *gemmæ* and by *stolons*.

**Thallophytes.**—The Thallophytes comprise the Algæ and Fungi (including Lichens). The vegetative structure is in the greater number of cases a simple one, since the plant usually consists of a thallus in which no distinction between root, stem, or leaf exists. The class includes organisms, however, of widely different degrees of development. The lowest forms (Protophytes) are composed of a single cell; and we rise, by almost imperceptible gradations, to the highest representatives, in which indications of leaf and stem appear, and a rudimentary differentiation of tissue exists. The functions of a root, when such are necessary, are performed by rhizoids, and by a kind of sucker called *haustorium* in those plants which live by parasitism. The class, from its comprehensive nature, includes an extraordinary number of forms, which can, however, mostly be classified into a comparatively small number of groups. In their life-history Thallophytes cannot be brought under one general rule, as in the case of the Cormophytes. In many cases a simple alternation of generations is the rule, while in others several generations form a life-cycle, certain links of which may, under circumstances, be omitted; but this is the exception.

FUNGI.—In the Fungi the vegetative body consists, with the exception of several doubtful cases, of filiform, more or less branched *hyphæ* or threads. In many instances the thread is one long densely ramifying bladder-like cell; but in most cases it consists of a series of cells placed end to end with dichotomous or lateral branches. Of such cells the large bodies of our familiar Fungi, as well as those of the minute species, are composed. The cohesion of the hyphæ is usually effected by their being densely interwoven in various ways. There is, however, found in some of the higher Fungi a kind of structure bearing a resemblance to the parenchyme of the higher plants; but, not being a tissue in the true sense of the term, it has been termed *pseudo-parenchyme*. The structure and growth of the fungal cell agree in essential

points with those of the vegetable cell as it occurs elsewhere. In the numerous Fungi which develop rapidly and have a short existence in the adult state, the cell-wall is thin, tender, and structureless; but the possession of a thick cell-wall of a homogeneous unstratified nature is not uncommon. Cases also occur (in the *Polyporei*, *Thelephora*, *Bovista*, *Geaster*, *Tulostoma*, &c.) in which, by the aid of sulphuric acid, solution of potash, or of Schultz's mixture, a cell-wall of two or more coats is found; and in certain instances simple immersion in water is sufficient to show a beautiful stratification. From the differences in chemical reaction the cell-membrane of Fungi cannot be called true cellulose, and it has therefore received the special name of *fungus-cellulose*. The protoplasm of Fungi differs in no respect from that of other plants, but it never contains either chlorophyll or starch. From this it follows that they cannot obtain their carbon directly from the carbon dioxide of the atmosphere, as Flowering Plants, Vascular Cryptogams, and Algæ do, but must be dependent for their nutrition on substances already organized. In other words, all Fungi are either *parasites* on other plants or on animals, or *saprophytes* (feeding on decaying organic matter). The cells of the higher Fungi contain a "nucleus"; in the lowest forms one has not yet been detected in all cases, but many physiologists are of opinion that this is simply the result of imperfection of observation. The protoplasm contains "vacuoles" and fatty oils; and pigments of various colours occur plentifully. Crystals of calcium oxalate are to be met with in the intercellular spaces of many Fungi, but in only a few cases have they been found in the interior of the cell. Cell-division and free cell-formation take place in the same way as in other plants.

The modes of reproduction of Fungi are extremely various, and are greatly complicated by the phenomenon of alternation of generations. The cycle of generations of a single species is often completed by two (or sometimes even more) forms, which are parasitic on totally different plants (*heterœcism*), and which differ from one another altogether in their external form and in their mode of reproduction. In some orders of Fungi a true sexual mode of reproduction is known, which will be described when we come to those orders; in others the female, but not the male, organs have been detected; in others no sexual organs at all have been discovered. In all, whether also reproduced sexually or not, there is a non-sexual mode of propagation by means of *spores*; and it is convenient to confine this term and its derivatives entirely to nonsexual organs of propagation. In the different orders of Fungi the spores vary greatly in their form and appearance, and in the part of the plant where they are formed; and to these different names

are given. Thus *zoospores* or swarm-spores are provided with vibratile cilia which endow them with a spontaneous power of motion in water; *ascospores* are formed within sacs or asci; *basidiospores* are formed at the apex of special cells known as basids; *chlamydospores*, when fully formed, are still enclosed within their parent-cells, &c. The spore is usually a single cell; sometimes it breaks up into secondary cells or *sporids*. The chamber within which the spores are formed is a *sporange*.

On germinating, the spore first gives rise to a germ-tube or *germinating filament*, which usually branches copiously into a dense tuft of hyphæ known as the *mycele*. From the mycele or spawn, which is commonly entirely buried in the tissues of the host or in the organic substratum, there often rises into the air a body composed of much more densely packed hyphæ, known as the *receptacle*, on which are usually borne the organs of reproduction, whether sexual or non-sexual. The receptacle is generally much the most conspicuous part of the fungus, the term fungus being often popularly confined to it, as in the case of the common mushroom.

LICHENS.—Until recently the Lichens were thought to occupy a position in the Vegetable Kingdom equal in rank to that held by the Fungi and Algæ; but from the more intimate knowledge of their structure and life-history obtained through the researches of Schwendener, De Bary, Stahl, Bornet, and others, it is necessary now to regard them as only an order of the great group of Fungi called *Ascomycetes*. The thallus and fructification are without doubt identical with those of the Ascomycetes; but there enters into the composition of the Lichen another important factor, in the form of minute algæ on which the fungal hyphæ lead a life of parasitism. The case may be shortly stated thus:—The green parts of the Lichen, called *gonids*, are minute algæ, which gather nourishment in a perfectly normal manner. The hyphæ of the fungal parasite extract this nourishment for their own use, and the balance of supply and demand is so preserved that both parasite and host continue to consort through life in a harmonious manner. To this singular mode of life, which has its analogue in the animal kingdom, the term *symbiosis* or *commensalism* has been applied. The gonids (algæ) must be looked upon as independent organisms, imprisoned and forced to serve the double purpose of providing for themselves and their parasites. At the same time they reproduce their own species. Their specific identity with members of the genera *Pleurococcus*, *Nostoc*, *Chroococcus*, *Scytonema*, &c., is well established. The parasites, on the other hand, are true ascomycetous Fungi, reproducing themselves in a strictly ascomycetous manner, and, instead of living on tissues which

sooner or later succumb to their demands, have selected hosts offering the greater advantage of persistent life. Of the two components the Fungus is the superior both in bulk and nature, and it is for this reason that the Lichens must be classed as Ascomycetes.

ALGÆ.—Algæ present, like Fungi, a gradation from excessively simple to higher forms, the thallus of which possesses a structure of a complicated nature. The thallus of the higher Algæ consists usually of a pseudo-parenchyme; and in some instances a seeming differentiation of tissue into epiderm and fundamental tissue is exhibited, though the so-called epiderm must be regarded as having an analogy only to true epiderm. The cell-walls consist of unlignified cellulose, which shows a blue colour on the application of iodine and sulphuric acid. Many Algæ are enveloped in a gelatinous substance, which is produced by a process of degradation of the cell-wall. Others again, owing to the deposition of calcium carbonate in the cell-wall, or its excretion into the intercellular spaces, attain a calcareous structure, as in *Corallina*. The gelatinous substance serves as a means of fixing the plant to its station, and the calcareous or silicified coats form a valuable protection. Usually, if not always, the cells possess a nucleus, and in some Algæ with very large cells each contains several nuclei. Starch occurs frequently; and chlorophyll, often covered by pigments of various colours (which can easily be removed by cold distilled water), is always present. The Alga, therefore, unlike the Fungus, is able to obtain its nutriment directly from carbon dioxide and the inorganic salts dissolved in fresh or salt water. A parasitic life, however, does occasionally occur among the Algæ. The large Algæ (such as *Macrocystis*) often attain colossal dimensions and a tree-like form, while the filamentous plants form wavy masses sometimes of considerable length. The reproduction of Algæ is effected by both sexual and non-sexual means; and these processes bear often a striking resemblance to those which occur in Fungi. The non-sexual mode consists usually in the separation of some merely vegetative part from the mother plant, such as the formation of zoospores or the detachment of *gemmæ*. In the sexual mode of reproduction a variety of processes obtain which will be described when the families in which they occur are treated of.

The Order CHARACEÆ forms a link of connexion between Algæ and Cormophytes.

PROTOPHYTES.—Under this head it is convenient to include the lowest forms of vegetable life, in which the individual consists, even when mature, of only a single cell, which performs all the

functions of life, both vegetative and reproductive, and in which therefore any sexual mode of reproduction is necessarily wanting, propagation taking place by means of simple division (gemmation) or by the formation of spores or zoospores. Some of these organisms are probably stages of development of Algæ or Fungi of a higher degree of organization. It is extremely difficult to draw a line of demarcation between the Protophytes and the lowest forms of animal life such as the infusorial animalcules; and some forms of life appear to partake at one period of their existence of an animal, at another period of a vegetable, nature. The Protophytes naturally divide themselves into two groups—the *Protophyceæ*, which contain chlorophyll, the starting-point of the Algæ, of which *Protococcus* is a good example; and the *Protomycetes*, destitute of chlorophyll, the starting-point of the Fungi, to which belong *Saccharomyces* (*Torula*), and the *Bacteria*, so important in the economy of life as being the invariable accompaniments or originators of fermentation and putrefaction, and the cause of many of the diseases of man and other animals. Many writers distribute the Protophyceæ and Protomycetes among Algæ and Fungi respectively.

We now proceed to examine more in detail the structure and mode of development of the more important groups of Flowerless Plants.

# CLASSES

OF

# FLOWERLESS PLANTS.

## Subdivision I. CORMOPHYTES.

Cryptogamic plants usually provided with stems, leaves, and roots, or their morphological equivalents.

Under this head are associated a number of vegetable forms which are closely allied to Phanerogams in the details of their vegetative structure, but which are separated from them by the mode of their sexual reproduction. On the other hand, the vegetative organs are morphologically and physiologically of similar value in Cormophytic Cryptogams and Phanerogams. Among Cormophytes the *Filices* represent the highest degree in the scale, with stem, root, and leaf exhibiting a very high degree of development. Passing over the less sharply marked degrees in the scale, represented by other Vascular Cryptogams,—in the Mosses, though stem and leaf are present, there is no true root, its place being, however, supplied by organs of corresponding physiological value. In the stem and leaf, too, we no longer find the relations so perfect, since there is no perfectly organized vascular tissue, but only an indication of it. The anatomical structure of the *Hepaticæ* is still lower in the scale, and approaches that of the Thallophytes more nearly than any other Cormophytes. The life-history of Cormophytic Cryptogams consists of two distinct generations—a sexual alternating with a non-sexual one.

### Class I. *Vascular Cryptogams.*

Cormophytic Cryptogams possessing vascular tissue.

The Vascular Cryptogams consist of the *Selaginellales*, the *Rhizocarpeæ*, the *Equisetales*, the *Filicales*, and the *Lycopodiales*. The form in which the plants are commonly seen and known, and in which they attain the highest point of development in their vegetative structure, is the non-sexual generation. They possess in this stage both cellular and vascular tissues, organized in some cases (*Filices*) on perhaps the most perfect system possessed by any known vegetable. Their life-history begins with the germination of a non-sexually produced *spore*, which gives rise to a *prothallium*, usually consisting of a single layer of cells, on which are borne *antherids* (male organs) or *archegones* (female organs), or both. The antherids produce *antherozoids* or spermatozoids, which fertilize the archegones out of which the non-sexual spore-bearing generation springs (see figs. 6, 7, p. 26).

Vascular Cryptogams are divided as follows:—

Subclass i. **Heterosporia.** Spores of two kinds.

Series 1. Selaginellales.

„ 2. Rhizocarpeæ.

Subclass ii. **Isosporia.** Spores of one kind.

Series 1. EQUISETALES.
„ 2. FILICALES.
„ 3. LYCOPODIALES.

## Subclass i. Heterosporia.

Vascular Cryptogams producing spores of two kinds, *megaspores* or macrospores, and *microspores*. The megaspores develop a female prothallium, which remains attached to the spore, bearing the archegones; the microspores produce a rudimentary male prothallium, which also remains attached to the spore and develops antherozoids.

The two Series which make up the Heterosporia differ from the three remaining series of Vascular Cryptogams in the greater differentiation of their sexual organs. The archegones are borne on female prothallia, which are produced within comparatively large spores developed non-sexually, the *megaspores* or macrospores. These are contained in comparatively small numbers in special receptacles, the *megasporanges* or macrosporanges. The prothallium never becomes completely detached from the spore so as to carry on an independent existence. Only a very imperfect rudimentary prothallium intervenes in the production of the male organs or *antherozoids* within much smaller spores, the *microspores*, produced in larger numbers within other special receptacles, the *microsporanges*.

### Series 1. SELAGINELLALES.

Female prothallium concealed within the megaspore. Male prothallium rudimentary within the microspore, and giving rise to the mother-cells of the antherozoids. Leaves with a ligule above the base, beneath which is the sporange containing numerous microspores or four megaspores. Archespore, from which the spores are developed, unicellular.

SELAGINELLACEÆ.—*Non-sexual Generation or Sporophore*: Stem slender, dichotomously branched in one plane; leaves ligulate at the base, small, appressed in four vertical rows, the two upper or anterior rows usually different from the lateral ones. Sporanges axillary; megaspores 2–4–8; microspores numerous.—*Sexual Generation or Oophore*: Megaspores producing female, microspores rudimentary male prothallia.

**Structure and Life-history.**—The leaves are simple and have a single vascular bundle. In germination the microspore divides into several cells, of which one, regarded as a rudimentary male prothallium, is sterile, and the others produce antherozoids. The megaspores produce the female prothallia by developing within themselves a mass of cells, while the wall of the endospore begins to increase in thickness and separates into layers. Owing to the cell-division within, the exospore bursts along its three angles, and after some time the prothallium pro-

trudes and bears one or more archegones on its exposed portion. Fertilization by means of antherozoids takes place in the manner common to all Vascular Cryptogams, and the non-sexual generation or sporophore arises from the fertilized oosphere. Occasionally the sexual generation appears to be entirely suppressed, a new non-sexual generation springing directly from the fovea or pit of a leaf. This is an example of *apogamy*, a phenomenon best illustrated in the case of Ferns.

**Affinities, &c.**—This Order is allied in its vegetative structure to Lycopodiales, while it differs from that group in the nature of its sexual reproduction. The *archespore*, from which the spores are developed, according to Gœbel, is unicellular, the *tapete* or cellular lining of the sporange being derived partly from the archespore, partly from the tissue of the sporange. From Rhizocarpeæ the Order differs widely in its vegetative structure.

*Selaginellaceæ* are usually low trailing plants, inhabiting damp places especially in warm countries. Many are cultivated for the elegance of their form.

ISOËTACEÆ.—*Non-sexual Generation*: Stem perennial, cormlike, internodes undeveloped: leaves tufted, broad and spreading at the base, linear, traversed by four air-canals and one central vascular bundle. Sporanges of both kinds, in the fovea or pit at the base of the leaves. Megaspores and microspores numerous; archespore multicellular.—*Sexual Generation*: Prothallium as in Selaginellaceæ.

**Structure and Life-history.**—Similar to that of Selaginellaceæ, with the exception of those of the vegetative organs. The corm of *Isoetes* is perennial, and of woody structure when old, being nearly the only instance known among Cryptogams of a permanent increase in the thickness of the stem. This takes place almost entirely in two or three spots directly opposite one another, causing the stem ultimately to assume the form of a plate or disk. The archespore is multicellular, and the tapete is derived from it, according to Gœbel.

The species of *Isoëtes* grow in the mud at the bottom of pools.

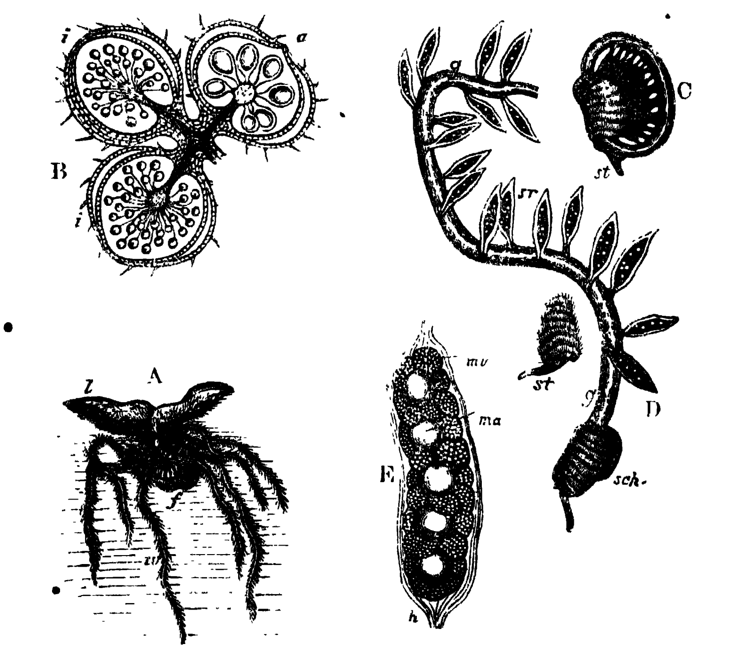
### Series 2. Rhizocarpeæ or Hydropterideæ.

Female prothallium not detached from the megaspore. Male prothallium rudimentary, giving rise to the mother-cells of the antherozoids. Stem branched; leaves distichous. Roots from the lower surface of the stem. Sporanges in *sori* or clusters within uni- or multilocular sporocarps formed from metamorphosed leaves. Microspores and megaspores numerous, but only one of the latter comes to maturity. Stem with a 2-3-sided apical cell; root with a 3-sided apical cell. Archespore of a single cell from which the tapete and the mother-cells of the microspores are developed.

SALVINIACEÆ.—Floating plants with (*Azolla*) or without roots (*Salvinia*). Sori unisexual, each contained within a unilocular sporocarp. Spores invested by hardened mucilage. Prothallium with numerous archegones.

**Structure, &c.**—In *Salvinia* the male organs are produced by the protrusion from the microspore of tubes, each of which divides into two cells at the apex ; the apical one of these is regarded as a rudimentary antherid, and from its contents are formed the antherozoids.

The number of spore-mother-cells is originally the same in both microsporanges and megasporanges, viz. 64; but in the former all develop into spores, while in the latter all become disorganized except one, which increases enormously in size into the single megaspore. The disorganized spores become converted into a frothy protoplasm, which subsequently hardens into the *epispore*, a thick outer coating of the mature megaspore, developed especially at its apex. It splits over the apex of the spore, so as to allow of the protrusion of the prothallium. In *Azolla* this frothy mucilage occurs in both kinds of sporange, and is still more conspicuous. In the microsporange it forms from two to eight separate lumps, the *massulæ*, each enclosing a number of microspores.




*Salvinia natans.* A, section through the plant, showing the whorls of aerial leaves *l*; at *w* the submerged leaves are shown bearing *f*, the sporocarps, nat. size. B, longitudinal section through three fertile teeth of a submerged leaf, showing at *a* a sporocarp with megasporanges, and at *i i* two sporocarps with microsporanges · magnified.
*Marsilea salvatrix.* C, sporocarp which has burst in water and is protruding its gelatinous ring (Hanstein), *st*, upper part of stalk. D, the gelatinous ring: *g*, ruptured and extended; *sr*, compartments of the sporocarp; *sch*, shell of the sporocarp. E, compartment from a ripe sporocarp; *mi*, microsporanges; *ma*, megasporanges.

MARSILEACEÆ.—Plants rooting in moist earth. Leaves circinate. Sori bisexual, including both megasporanges and microsporanges. Spores invested by hardened mucilage. Prothallium with a single archegone.

**Structure, &c.** In *Marsilea* and *Pilularia* the antherozoids are formed within the microspore, thus: first eight cells are formed, and then the contents of each produce four antherozoids—32 in all. The antherozoids escape through a small funnel-like opening at one end of the microspore. The female prothallia are produced from the megaspores: they remain enclosed at first by the funnel at the apex of the megaspore, and are bounded on the underside by a diaphragm, which separates it from a large intercellular space within. The funnel at the apex then opens asunder, and the prothallium is almost entirely protruded by a bulging motion of the diaphragm; on it are formed the archegones, which, after fertilization by the antherozoids, give rise to the non-sexual spore-bearing generation.

**Affinities, &c.**—The genus *Marsilea* with its allies, of which *Pilularia* is our only native example, is composed of herbaceous plants, the stem of which is but little developed, and consists of a kind of rhizome giving off tufts of filiform adventitious roots on the under side and two or more series of leaves on the upper side. They are found growing in the mud at the margins of pools.

**Qualities and Uses.**—They have no known medicinal or economic properties; the spores of *Marsilea salvatrix*, the Nardoo of Tropical Australia, are eaten by the natives in times of scarcity.

## Subclass ii. **Isosporia.**

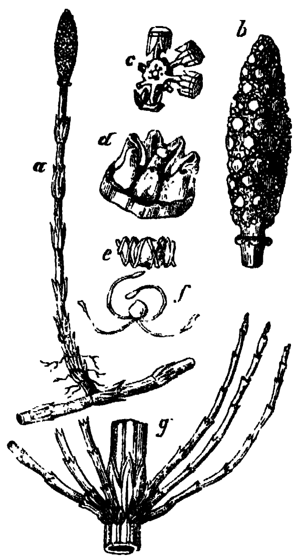
Vascular Cryptogams producing spores of one kind only. Prothallium growing free from the spore and producing antherids and archegones. The prothallia are occasionally diœcious, but there is then no apparent differentiation between the spores which produce male and female prothallia.

### Series 1. EQUISETALES.

*Non-sexual Generation*: Herbaceous plants with jointed subterraneous rhizomes, sending up at intervals fistular jointed furrowed stems, bearing whorls of scale-like leaves at the joints, where they are sometimes verticillately branched. Spores borne on metamorphosed leaf-bearing stems, terminating in a clavate apical segment covered with dehiscent sporanges. Spores triple-coated, of one kind, with two elastic filaments called *elaters*, formed by the spiral fission of the outer coat of the spore. Stem, rhizome, and root grow longitudinally by means of a single apical cell, giving off three series of segments. Vascular bundles arranged in a circle.—*Sexual Generation*: arising from the spore, consisting of independently subsisting usually diœcious prothallia, the male prothallia being smaller than the female.

**Structure and Life-history.**—The Equisetales at present existing consist of a single genus, *Equisetum*, a small group of herbaceous plants, with a creeping subterraneous jointed but solid rhizome (fig. 4, *a*), from which arise erect shoots or stems. The stems are striated longitudinally, jointed at intervals, with circles of small and narrow membranous scale-like leaves at the nodes, forming the *leaf-sheaths*, and fistular like the stems of Grasses. They are traversed by several air-canals, varying in number and disposition according to the species. The stems are sometimes simple, sometimes compound, bearing whorls of branches at the nodes, which branches resemble the main stem in character, and frequently branch again in a similar manner at their nodes. The erect stems are either fertile or barren (metamorphosed or true); in some species the fertile stems are short and simple, while the barren stems are tall and provided with numerous whorls of spreading compound branches. The fertile stems terminate in a kind of club or spike (fig. 4, *b*), composed of a short axis closely covered with *sporanges* (*c*); these are small peltate or mushroom-shaped bodies (*d*) attached by their stalks to the central axis, and bearing under the overhanging head a circle of vertical, tooth-like pouches (*d*), resembling the anther-cells of *Thuja* among Conifers, which burst by a vertical slit on the inside to emit the spores when ripe. The spores are furnished with filiform processes, called *elaters* (fig. 4, *f*), formed by the splitting into narrow strips and the partial detaching of the *exospore*, or outermost of the three coats of the spore, and unwinding with elasticity when the spore is discharged from the sporange. From their hygroscopic properties they assist in the dissemination of the spores. The erect stems die down annually, while the rhizome persists.

Fig. 4.




Structure of Equisetaceæ:—*a*, fertile stem of *Equisetum arvense*, arising from the rhizome; *b*, fertile spike (nat. size); *c*, transverse section of do., showing how the sporanges are attached to the axis; *d*, a group of sporanges seen from beneath; *e*, a spore; *f*, the same, with its elaters uncoiled; *g*, fragment of the branched stem of *E. palustre*.

The spore of Equisetales contains a nucleus and chlorophyll granules; and it is, perhaps, owing to this high state of internal organization that its powers of germination are retained for only a few days at the most. The first sign of germination is an enlargement of the spore and the assumption of a pear-like form, during which it divides into two cells; the smaller, possessing almost colourless contents, grows out in the form of a long rhizoid, and the other, containing the chlorophyll of the spore, by repeated cell-division ultimately produces the prothallium. The prothallia of Equisetales are small, flat, chlorophyll-containing bodies, consisting, in some parts, of several

layers of cells, and supplied with irregular arm-like lobes. They are usually diœcious, and bear the sexual organs—antherids or archegones as the case may be. The male prothallia are usually a few millimetres long, and the female often as much as half an inch. The antherids are produced at the end of the large and between two smaller secondary lobes of the male prothallia. They contain upwards of 100 large antherozoids (the largest produced by any Cryptogam), which are at first enclosed within a sac or membrane; on being set free from this, they at once begin to swim about with an undulatory motion. The archegones arise at the base of the lobes of the female prothallia, and consist each of a few cells so arranged as to form a canal leading to a central cell of the archegone, which is fertilized by an antherozoid through the conductive agency of the canal. Immediately after fertilization the canal-cells close, the central cell begins to increase in size, and the cells of the neighbouring tissue undergo a corresponding increase in number. By-and-by the *oosperm*, or fertilized protoplasmic contents of the central cell, also divides; and, after the division has been often repeated, differentiation of the resulting cells commences. The growth proceeds by an apical cell; and a leaf-bearing shoot with a rhizome and root is soon to be seen and recognized. When the *Equisetum* has attained maturity, the non-sexual spores are again borne on the erect metamorphosed stem, and so the life-history proceeds in the alternating sexual and non-sexual generations. The rhizome has a strong tendency to produce tubers.

**Affinities, Qualities, &c.**—The structure of *Equisetum* is very unlike that of any other Cryptogam. In external appearance the stems have no little resemblance to those of *Ephedra* and *Casuarina*; but their internal organization is totally different. They resemble Grasses in having a deposit of silex in the epidermal tissues of fistular erect stems, in *E. hyemale*, known as Dutch Rushes, so abundant that the ashes of the stem form a good polishing-powder, like fine tripoli.

**Distribution.**—*Equisetums* or Horsetails are found in wet and sandy places in most parts of the globe. The fossil Calamites of the Carboniferous and other rocks appear to have been gigantic representatives of the Equisetales; the structure of the stem presenting a very strong resemblance to existing forms, and some even find the spores to have been furnished with elaters. *Asterophyllites* and *Sphenophyllum* are regarded by some as the foliage of the Calamites.

## Series 2. FILICALES.

*Non-sexual Generation*: Herbs with a subterraneous rhizome, or trees with an unbranched caudex, with well-developed generally more or less divided or compound leaves, usually circinate in vernation, and all or part bearing clusters of sporanges (*sori*) upon the lower surface (fig. 5, *a*, *b*, *d*) or at the margins (*g*), seated upon branches of the veins, or sometimes placed on a special branch of the leaf. The sori are either naked (*b*), or covered at first by a variously formed dehiscent or separating membranous structure

(*indusium*, *d*, *e*), which is continuous with the epiderm of the leaf. The sporanges are usually metamorphosed trichomes, developed out of a single epidermal cell, less often from a group of cells. The apical cell gives off, in the stem, either two or three series, and in the root always three series of segments. The vascular bundles are very strongly developed, and the central xylem, composed chiefly of scalariform tracheids, is surrounded by weak phloëm, without any intervening cambium; they are therefore *closed* bundles.—*The Sexual Generation*, arising from the spore, consists of an independently subsisting monœcious prothallium. Archespore unicellular.

**Structure and Life-history.**—The Filicales or Ferns exhibit a far greater variety of conditions than the Equisetales. Their most remarkable character is the great development of the leaves, the stems being represented in most cases by a rhizome, although in some exotic forms it becomes a real trunk, but is then almost always unbranched. The vascular bundles are arranged in a circle near the periphery in the stem, while in the root they form a single axial bundle; they are closed, and are distinguished by the abundance of scalariform tracheids. They are separated from the cortical and medullary tissues by an enveloping *vascular bundle-sheath*, which is often again enclosed in a strongly lignified dark brown *sclerenchymatous* layer. Even the erect stems frequently produce abundant roots. *Lygodium scandens* has climbing leaves. The apex of the stem is always occupied by a single, clearly distinguishable apical cell.

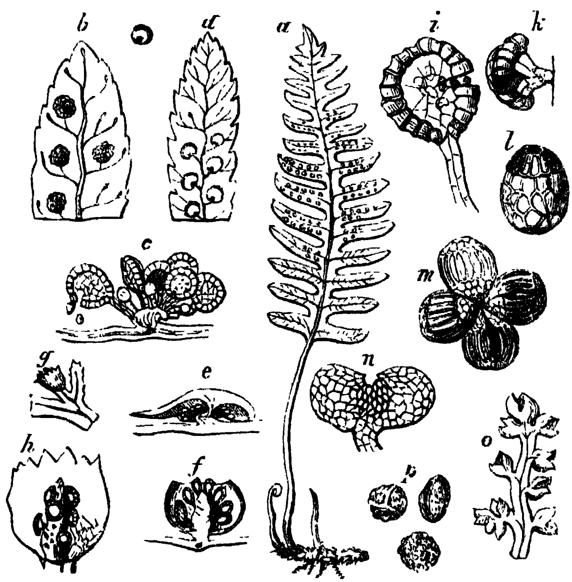
The rhizomes of the herbaceous kinds are subterraneous, and grow either horizontally or vertically. In the former the internodes are either developed or undeveloped; when they are developed, the leaves arise singly from the ground, as in the common brake (*Pteris aquilina*) and *Polypodium vulgare* (fig. 5, *a*); when the internodes are undeveloped, the leaves are tufted, which is always the case when the rhizome is erect, as in *Athyrium filix-fœmina*; and the arborescent kinds likewise exhibit the tufted growth of the leaves from a terminal bud, with little development of the internodes. The rhizomatous stems frequently branch, in which case the stem bifurcates, as in Lycopodiales.

The leaves, commonly called "fronds," of Ferns resemble those of flowering plants in their essential structure; they are sometimes quite simple, but often very remarkable for their extreme subdivision. The venation of the leaf is most commonly on a bifurcate plan (fig. 5, *b*, *d*), the subdivisions retaining an equal size. The leaves are also characterized by the circinate vernation, which is almost universal except in the Ophioglossaceæ. In the Hymenophylleæ they are semitransparent, being reduced to a single layer of cells, and are then destitute of stomates, which are present in other cases. The leaf-stalks are frequently covered with dry brown or golden yellow epidermal structures, known as *paleæ* or ramenta. In the Marattiaceæ the leaves are provided with stipules. In some genera, as *Osmunda*, to which the so-called "flowering fern" belongs, there is a strong tendency for the fructification entirely to replace the green parenchyme of the leaf in its upper part.

The fructification of Ferns is produced upon the leaves, usually on the

under side only, in the Hymenophylleæ on the margin; but in the Ophioglossaceæ on a distinct branch. In some Ferns (*Lomaria spicant*, *Allosorus crispus*, &c.) the fructification occurs only on certain leaves, which are termed fertile, and are distinguished from the barren fronds by the very small development of the mesophyll. It presents a great variety of modifications, which serve to characterize the principal subdivisions of the Series. The *spores* are formed in *sporanges*, little membranous sacs attached by a pedicel to the lower surface of the leaf (fig. 5, *b*, *c*, *i*, &c.),

Fig. 5.




Structure of Ferns.—*a*, plant of *Polypodium vulgare*. *b*, fragment of a pinna with naked sori; *c*, vertical section through one of the sori, showing the attachment of the sporanges to the leaf; *d*, portion of a pinnule of *Nephrodium filix-mas*, the sori covered with indusia; *e*, vertical section through a sorus of the same, showing the attachment of the indusium and sporanges; *f*, vertical section of a cup-shaped indusium and sorus of *Cyathea*; *g*, marginal sorus of *Hymenophyllum*; *h*, the same, with one valve removed, to show the attachment of the sporanges; *i*, sporange of *Polypodium*, bursting; *k*, sporange of *Hymenophyllum*; *l*, sporange of *Schizæa*; *m*, group of sporanges of *Mertensia*; *n*, sporange of *Osmunda*; *o*, portion of the fertile lobe of the frond of *Botrychium Lunaria*, with the sporanges burst. *p*, spores of Ferns.

or to a kind of skeleton of the leaf in which the parenchyme is suppressed (*o*). The sporanges are always formed in connexion with the veins of the leaves; in the Hymenophylleæ on a prolongation of the midrib beyond the margin, and enclosed in a kind of cup (fig. 5, *g*). These spore-cases differ in some important points of structure, in the mode of attachment,

and in their relations to each other. In most Ferns they possess an *annulus* or ring (fig. 5, *i*), an incomplete row of thickened cells running round the sporange, and assisting, by its contraction when dry, to rupture the sac and set free the spores. In the *Polypodieæ* and other tribes it is vertical (fig. 5, *i*); in the *Hymenophylleæ* the ring is oblique and unconnected with the basal pedicel (*k*); in the *Gleicheniææ* it is horizontal (*m*); and in the *Schizæeæ* it forms a kind of cap with radiating striæ on the top of the spore-case (*l*); in *Osmundeæ* the ring is broad, but imperfectly developed (*n*), while in Marattiaceæ and Ophioglossaceæ (*o*) it is absent altogether.

In the true Ferns the sporanges are distinct from one another, but collected in groups (*sori*) of various forms, round, linear, &c. (fig. 5, *b*, *c*), on the lower surface of ordinary leaves, or of leaves especially devoted to the fructification, and modified in form and texture. In *Lygodium* each sporange is enclosed in a pocket. The *sori* are either *naked* (*b*, *c*), or covered by a membranous cover or *indusium* (*d*, *e*), the forms and modes of attachment of which furnish systematic characters. In the Marattiaceæ and Ophioglossaceæ the sporanges are usually more or less coherent together, so as to form a false compound multilocular sporange. In the typical Ferns the sporanges are trichomic structures, developed from a single epidermal cell; but in the Marattiaceæ and Ophioglossaceæ they originate from a group of cells. In the *Hymenophylleæ* the sporanges are attached to little columns formed by the production of the ribs beyond the margins of the leaves (*g*, *h*), becoming at the same time enclosed in cup-like receptacles formed from the margins of the leaf. In the Ophioglossaceæ a portion of the leaf is transformed into a simple or compound spike-like process, covered with free sporanges destitute of a ring, and splitting regularly to discharge the spores (*o*). The *spores* are simple cells of microscopic dimensions, furnished, like pollen-grains, with a double coat, the outer of which is generally similarly marked with papillæ, reticulations (*p*), &c.

The arborescent Ferns belong to the Polypodieæ and Cyatheæ, and differ only in habit and dimensions from the more familiar forms.

Ferns are sometimes reproduced by buds, analogous to bulbils, formed on different parts of their structure, and sometimes at the points of the leaves, as in *Asplenium bulbiferum*, &c.

The spores of Ferns retain their germinating power longer, as a rule, than those of Equisetales. They have usually a granulated appearance, with a cuticularized exospore. On germinating, the exospore bursts, and the contents, already divided into several cells, are protruded, and develop the prothallium. The prothallia of Ferns differ from those of Equisetales in being generally more regular in outline. They produce numerous rhizoids, and are self-supporting. The antherids and archegones differ but slightly from those of Equisetales. The antherids are situated on the margin or surface, and the archegones on the surface of the prothallia. They are monœcious, but show in some cases a tendency to be diœcious. After the central cell of the archegone has been fertilized by an antherozoid, the non-sexual generation arises from it in a similar manner to that in Equisetales.

A remarkable exception to the ordinary mode of reproduction in Ferns occurs occasionally in the case of *Pteris cretica* and some other species,

where no female organs are formed on the prothallium, though the male organs attain full development and produce antherozoids. The leaf-bearing generation springs from the prothallium in a purely vegetative manner, and is occasionally observable in other cultivated Ferns. This replacement of the female sexual organs by a non-sexual generation, which occurs elsewhere in Cryptogams, is known as *apogamy*. In a cultivated variety of *Athyrium filix-fœmina* and some other species, the correlative phenomenon of *apospory* has been observed, the sporanges being more or less completely replaced by prothallia borne directly on the frond. *Gymnogramme* is distinguished by the persistence of its prothallium.

Fig. 6.

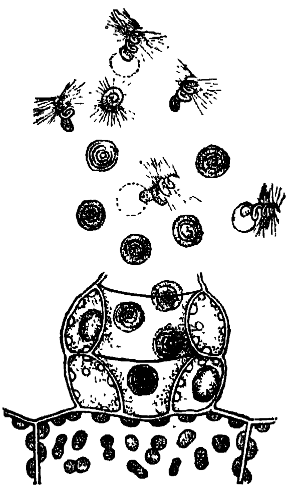


Fig. 7.

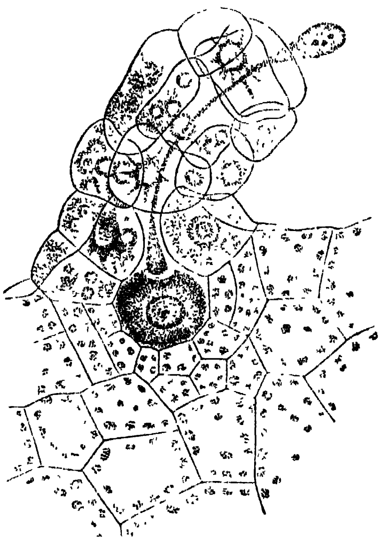


Fig. 6. Antherid of *Pteris cretica*, at the moment of escape of the antherozoids.
Fig. 7. Archegone of *Pteris cretica*, at the moment of the expulsion of mucilage from the canal, at the base of which is seen the central cell containing the oosphere.

*Classification.*—This very large Series may be divided, as under, into three Orders, which for convenience are treated together.*

I. FILICES.—Sporanges on the back or margin of the leaves, not coherent, and entirely of epidermal origin. Leaves not stipulate, circinate in vernation. Prothallium foliaceous.

Suborder 1. POLYPODIEÆ. *Sporanges stalked, with a vertical annulus.*
Suborder 2. CYATHEÆ. *Sporanges sessile, more or less elevated on a common receptacle; annulus vertical. Mostly tree-ferns.*

Suborder 3. PARKERIEÆ. *Sporanges thin, with a broad imperfect vertical annulus.*

Suborder 4. HYMENOPHYLLEÆ. *Sporanges on an axis produced by the excurrence of a vein beyond the margin of the leaf; annulus horizontal or oblique. Prothallium resembling the protoneme of a moss.*

Suborder 5. GLEICHENIEÆ. *Sporanges commonly arranged in fours in the dorsal sori, nearly sessile, with a transverse or oblique annulus, bursting vertically on the inside.*

Suborder 6. SCHIZÆEÆ. *Sporanges dorsal; the annulus in the form of a cap on the summit; dehiscence vertical.*

Suborder 7. OSMUNDEÆ. *Sporanges stalked, dorsal, or arranged on pinnæ assuming a spiked or paniculate aspect from the absence of parenchyme between the veins; annulus incomplete, dorsal; dehiscence across the vertex.*

2. MARATTIACEÆ.—Sporanges on the backs of the leaves, and coherent into a many-celled sorus, opening by a pore, each developed from a group of cells. Leaves circinate, usually of great size, and furnished with stipules. Prothallium foliaceous.

3. OPHIOGLOSSACEÆ.—Leaves not circinate in vernation; sporanges developed from a group of cells, 2-valved, on special fertile branches of the leaves, without annulus. Prothallium a subterraneous mass of tissue, without chlorophyll.

**Affinities, &c.**—The Filicales constitute a very large and natural group of Cryptogamic plants which have no very close relations, as regards general structure; but the Ophioglossaceæ seem to form a link between Osmundeæ and Lycopodiales. As regards the physiological processes occurring in reproduction, they must be classed with Equisetales. There is, however, great diversity of habit in the vegetative body. The sporanges of the Marattiaceæ appear to resemble those of the Lycopodiales; but the development of the young spores agrees with that of true Ferns and Equisetales.

**Distribution, &c.**—The Ferns at present existing strongly resemble the fossil Ferns, many of which have been preserved, even as to the details of their structure, with wonderful perfection. They were very abundant in the Carboniferous epoch, and traces are also found in the Devonian. Ferns are universally distributed, more abundantly, however, in damp mild climates, which favour the development of foliage. The Ferns of temperate climates in the northern hemisphere are herbs, mostly perennial: in the islands of the tropics and the south temperate latitudes arborescent forms occur having the habit of Palms. The Marattiaceæ are all tropical, many of them tree-ferns with leaves several feet in length. Ophioglossaceæ are sparingly represented in Europe and North America, the West Indies, at the Cape, Tasmania, &c., but are most abundant in the East Indian islands.

**Qualities and Uses.**—Very few species have active properties, astringent, anthelmintic, and emetic qualities, &c.; the rhizome of *Pteris* &c., and

the stem of some arborescent kinds, afford a poor nutriment, used by the aborigines of the South-Sea Islands and elsewhere in times of scarcity. *Nephrodium filix-mas* is officinal as an anthelmintic. A very large number of ferns are cultivated for the beauty of their foliage.

## Series 3. LYCOPODIALES.

*Non-sexual Generation*: Herbaceous or, rarely, shrubby plants with creeping stems, clothed with small usually closely imbricate leaves traversed by one simple vascular bundle; branches of the stem and root almost always dichotomous, without an apical cell. Sporanges arising from short stalks in the axils or at the base of the leaves on short pedicels; containing numerous tetrahedral spores of one kind.—*Sexual Generation*: Prothallia subsisting independently, and monœcious.

**Structure and Life-history.**—The Lycopodia, the Club-mosses or Stag's-horn mosses, have slender stems, with an erect or creeping habit. *Psilotum triquetrum* is an erect almost leafless shrub, entirely destitute of roots, their function being performed by underground branches of the stem. The size and form of the leaves vary. They are always simple, undivided, sessile with slender bases, and arranged either spirally or in a verticillate manner, but sometimes in both ways on the same plant. Adventitious roots are usually given off at the forks of the stem. The sporanges are considerably larger than those of Ferns, reniform, and placed in the axils of leaves, which are sometimes ordinary foliage-leaves, but are more often modified, and form dense terminal cone-like spikes. The vascular bundles of the stem and root are very characteristic, forming a large axial cylinder, within which lie bands of xylem, and enclosed in a well-developed bundle-sheath. *Psilotum* and *Phylloglossum* are distinguished by the presence of *cladodes* or leaf-like branches. The early stages of development are not well known. The prothallia possess rhizoids, and are self-supporting and monœcious. They bear antherids and archegones on their upper surface. The phases in the development of the embryo are not yet fully known. The vascular bundles of the stem contain several xylem-bundles, surrounded and separated from each other by phloem. The leaves are destitute of a ligule.

**Affinities, &c.**—The immediate relations of this Series are with the Selaginellales.

**Distribution.**—The species of *Lycopodium* are widely diffused throughout the world, but are most abundant in warm countries. *Psilotum* is a native of the tropics of both hemispheres and of Australia. The fossil *Lepidodendron* and *Sigillaria* were undoubtedly the stem, and *Stigmaria* the roots, of gigantic plants allied to *Lycopodium*, which were enormously abundant, especially in the Carboniferous period. *Lepidostrobus* is the fructification of some similar form of vegetation; but, as there are indications of two kinds of spore, it may have belonged to the Selaginellaceæ rather than to the Lycopodiaceæ.

**Qualities and Uses.**—It is asserted that some kinds of *Lycopodium* are poisonous. *L. clavatum* has been used as an emetic. *L. Selago* and *L. catharticum* are purgatives; the latter is very violent in its action. The powder used by druggists for enveloping pills, and known as *Lycopodium*, consists of the spores of a species of this genus. They are very inflammable, and are hence used for theatrical purposes.

## Class II. *MUSCINEÆ.*

Cormophytic Cryptogams possessing imperfect vascular tissue only or none at all.

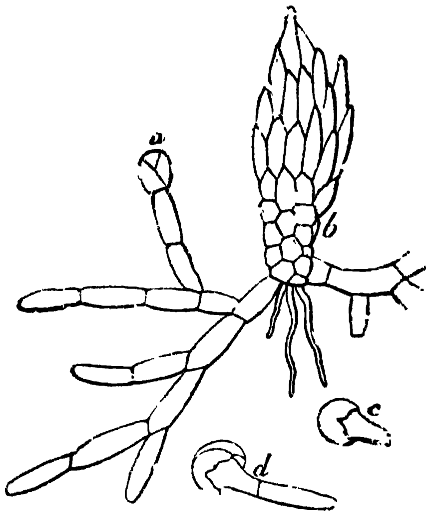
The *Muscineæ* consist of the Musci and Hepaticæ, and resemble Vascular Cryptogams in the fact that their life-history consists of two alternating generations—a sexual and a non-sexual. When the spore borne by the non-sexual generation germinates it produces the sexual generation—indirectly in the case of Musci and a few Hepaticæ, by the production of a *protoneme* (a confervoid prothallium), out of which the sexual generation arises; but directly in the other Hepaticæ. The sexual generation bears the *antherids* and *archegones*. From the fertilized central cell of the archegone there arises the non-sexual generation or *sporogone*, which, in the course of its development, forms in a non-sexual manner the spores, and these in turn produce the sexual generation. The chief contrast between Muscineæ and Vascular Cryptogams consists in the fact that whereas in Mosses it is the sexual generation which preponderates, the leafy part which we ordinarily call the moss belonging to it, while the non-sexual generation is the more transient one, in Vascular Cryptogams the opposite is the case, the leafy part which we call the fern, club-moss, &c., belonging to the non-sexual generation, while the sexual generation is transient. There are, however, cases in which the relations approach each other. In *Gymnogramme*, among Ferns, it is the prothallium which forms the more persistently vegetating plant, while the non-sexual generation is reduced to very small dimensions. In *Anthoceros*, on the other hand, among Liverworts, the sporogone shows a greater vegetative tendency than is usually the case in Muscineæ, by continuing to grow in the basal part and produce here new spores after those on the apical part are already ripe.

In the lower forms of Muscineæ (most Hepaticæ) the non-sexual generation is thalloid, without distinction of stem and leaves, resembling therefore that of Thallophytes; while in the upper forms (some Hepaticæ and all Musci) there is a distinct differentiation of axis and appendicular organs. The antherids and archegones are borne either on the same plant or on distinct individuals. The mature antherid of Muscineæ is a spherical, ellipsoidal, or club-shaped body, with a longer or shorter stalk, the outer layer of its cells forming a sac-like wall, while each of its small and very crowded internal cells becomes an antherozoid. These bodies are freed by the rupture of the wall of the antherid at its apex; they are spirally coiled threads, bearing at their anterior end two long

vibratile cilia. In *Marchantia* the antherids and archegones are both collected on separate elevated structures called respectively the male and female *receptacles*.

The *archegones* are flask-shaped cellular bodies, with a long neck (fig. 10, *a*; fig. 11, *a*, *b*), found generally several together, commonly at the ends of shoots, surrounded by modified leaves, forming a kind of *perianth*.

Fig. 8.




Germination of the spore of a Moss (*Funaria hygrometrica*):—*c*, spore germinating; *d*, more advanced, and the first cell divided; *a* and *b*, nascent leaf-buds on the confervoid protoneme. Magn. 200 diam.

In the ventral portion is a large cell known as the *central cell*, and in the lower part of this cell a mass of protoplasm, the *oosphere* (fig. 11, *b*; fig. 10, *a*). From the central cell a row of cells passes through the neck, as far as the apical or *stigmatic* cells. Before fertilization this axial row of cells becomes converted into mucilage, which swells up and forces apart the four stigmatic cells. An open canal is thus formed, through which the antherozoids reach the oosphere. Both archegones and antherids are of very different value morphologically in the different families of Muscineæ.

When the oosphere is fertilized, it first becomes invested with a cell-wall, and then begins to grow by cell-division, forming a cellular body which causes the expansion of the original wall of the archegone (fig. 11, *e*). After a time this wall gives way, in Musci by a circumscissile dehiscence, so that the upper part is carried upwards (fig. 10, *e*, *c*), after-

wards becoming the *calypter* of the sporogone (fig. 9), while the lower part (fig. 10, *v*) remains as the *vaginule* (fig. 9, *c*). In Hepaticæ the sac of the archegone is usually ruptured in the upper part, and there is no cup-shaped calypter formed, the sac becoming ultimately the envelope, corresponding to the vaginule of Mosses, here often called the *epigone* (fig. 12 B, *a*). The sporogone has no independent existence, being nourished by the sexual generation.

The mode of development of the spores, which are simple cells with a double coat, or an inner wall of cellulose enclosed in a distinct cuticular layer, is as follows:—In the cellular rudimentary sporange concentric layers become differently metamorphosed; the central mass (in Mosses) is developed into the *columel*; the intermediate layers between the columel and the wall of the sporange, which produce the spores, after multiplying to a certain extent, form free cells from the whole contents of each cell; the walls of the original or parent-cells dissolve, and a cavity is formed, in which the free cells (parent-cells of the spores) lie loose. These cells become divided into four chambers by septa; and each of these chambers (special parent-cells of the spores) produces a single free cell from its whole contents. The last-formed cells, set free by the solution of their mother-cells, are the spore-cells, which when ripe are enclosed in a cuticular layer, often more or less marked with points or reticulations, like pollen-grains.

When the spores germinate, they produce a confervoid structure, the *protoneme* (fig. 8), from different cells of which are produced a number of buds (*a*, *b*); each of these develops into a new leafy stem, forming a tufted group of plants, which after a time fructify again by antherids and archegones.

## Series 1. MUSCI, or Mosses.

*Sexual Generation*: Plants of a diffused or creeping habit, usually terrestrial, with very small imbricated leaves arranged in from two to four rows. The stems are slender and contain no true vascular tissue; they branch in a monopodial manner. A true root is absent, but its functions are performed by root-hairs. The sexual generation arises as a lateral shoot from a protoneme produced by the non-sexual spore on germination. It bears the antherids and archegones—the former stalked and the latter sessile on a narrow base.—*The Non-sexual Generation* or *sporogone* is at first enclosed in the calypter, which, on being ruptured at the vaginule, is carried up on the apex, where the capsule which produces the spores is formed (figs. 9, 10). Within the capsule is a sterile mass of tissue called the *columel*. The epiderm of the capsule splits to permit the escape of the spores.

The antherids are elongated cylindrical sacs, not stalked (fig. 10, *b*), borne in the axils of leaves, sometimes scattered, but more frequently collected in axillary or terminal bud-like structures (*inflorescence*). They

are filled with a tissue which is ultimately resolved into the mother-cells of the antherozoids: these escape from the apex of the antherid (fig. 10, *b, c*) enclosed at first in a thick mucilaginous jelly; and finally each mother-cell discharges an antherozoid (*d*), which swims about freely in the moisture.

Fig. 9.

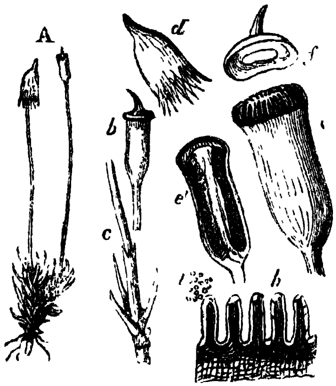



Fig. 10.

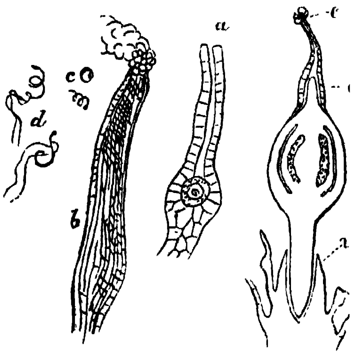



Fig. 9. Structure of Mosses:—A, *Polytrichum aloides*, natural size; *b*, its sporange, with opercule *in situ*, and calypter (*d*) detached; *c*, the base of the seta, with the vaginule; *e*, capsule, with peristome, magnified, and *e'*, a section of the same, showing the columel; *f*, the opercule of *e*; *h*, teeth of the peristome, from the mouth of *e*; *i*, spores, on the same scale of amplification as *h*.

Fig. 10. Antherid and archegone of Mosses:—*a*. vertical section of archegone with central cell from *Phascum cuspidatum*, magn. 100 diam.; *b*, antherid of *Polytrichum commune*, bursting to discharge antherozoids, magn 25 diam.; *c*, antherozoid of the same with its mother-cell, magn. 200 diam.. *d*, antherozoids of the same, magn. 400 diam.; *e*, immature fruit of *Phascum bryoides* (vertical section), *c*, calypter, *v*, vaginule, magn. 40 diam.

Both antherids and archegones are usually surrounded by an envelope of crowded and somewhat modified leaves, called the *perichæte*. These "receptacles" may consist of antherids only or of archegones only, or of both; when unisexual, the species may be either monœcious or diœcious. Within the perichæte, the sexual organs are accompanied by barren, tubular or club-shaped cells, the *paraphyses*. In *Polytrichum commune*, which is diœcious, the antheridial receptacles or "male flowers" are especially conspicuous in the spring. From the fertilized archegone rises the *sporogone*, which in its growth tears away the wall of the archegone, leaving the base as a kind of collar (*vaginule*, fig. 9, *c*), and carrying away the upper part, which finally becomes developed as a cap or hood, the *calypter*, *d*; this more or less encloses the urn-shaped *sporange*, theca, or capsule (*b*) until it is mature (fig. 9, A*e*); the stalk of the sporogone is called the *seta*. When the calypter falls off it exposes the capsule, which in most cases has a deciduous lid, the *opercule*, *f*.

Vegetative propagation may take place in Mosses from almost all parts of the plant, and in a great variety of ways, by the production of *gemmæ*, *bulbils*, &c. Under certain circumstances also the leaves may be made to produce a protoneme, a phenomenon similar to that of apospory in Ferns.

Cases of hybridism have been recorded in Mosses, and prolification of the antheridial receptacle is a common occurrence in *Polytrichum*.

When the opercule of the sporogone falls off, the border of the mouth of the capsule is found either naked (*gymnostomous*) or furnished with a single or double fringe of teeth or *cilia*, together constituting the *peristome*, fig. 9, *c*, *h*; and a circular piece, called the *annulus*, sometimes separates from the end of the columel in this place. The number of teeth in the peristome is either four or some multiple of that number. The capsule possesses stomates, the position of which and the number of teeth in the peristome are useful characters in classification. There is always a *columel* running through the sporange (fig. 9, *e'*). In the larger genera, like *Polytrichum*, there is considerable differentiation of tissue in the stem, but there are no true vessels.

**Classification.**—Mosses may be divided into four Orders as follows:—

1. BRYACEÆ. Plants tufted or creeping; monœcious or diœcious; leaves small, scale-like, usually spirally arranged; antherids and archegones produced in terminal buds or in the axils of the leaves.

2. PHASCACEÆ. Small moss-like plants with a short stem which remains attached to the protoneme till the spores are ripe. The sporange does not open by an opercule, and allows the escape of the spores only from its decay.

3. ANDREÆACEÆ. Cæspitose Mosses with erect stem and imbricate leaves, natives of mountains and polar latitudes. The sporogone is always terminal, and is destitute of a seta. The capsule is nearly sessile on the receptacle, where the vaginule arises and bursts vertically into four valves, which remain connected at the apex. A columel is present.

4. SPHAGNACEÆ, or Bog-mosses. The species are all aquatic or semi-aquatic, and of a peculiar yellowish-green aspect, with imbricate leaves and fasciculate branches, the lower of which are long and deflexed. The chlorophyll-containing cells of the leaves are slender and elongated; in the interstices are large empty or "hyaline" cells, the walls of which are strengthened by a spiral fibre. This structure causes the whitish or yellowish-green colour

peculiar to them and to a few similarly organized Mosses. The colourless cells, both of the leaves and of the epidermal layer of the stem, serve as a capillary apparatus for the plant, through which the water of the bogs in which it grows is raised all through the plant, as in a sponge. The stem consists of three distinct layers of tissue; some of the cells are very thick-walled, but not truly lignified. The antherids are globular stalked bodies, and resemble those of Hepaticæ more than those of other Musci. The sporogone possesses a short turbinate stalk or *pseudopode*, which is not homologous with the seta of true Mosses, and a globose capsule which dehisces by an opercule, and is destitue of a peristome; the columel is short and hemispherical; the calypter remains attached to the base. A peculiarity of the non-sexual generation is the existence of sporogones bearing spores of a smaller size than the ordinary large spores, which do not germinate, and the function of which is unknown. The protoneme is, under certain circumstances, a flat thalloid structure.

This Order is remarkable for the share it takes in covering bogs and gradually furnishing material for peat, the lower parts of the stems gradually dying away below while the summit ascends, owing to the power of the stems of indefinite apical growth; the descending lower branches of the fascicles bind the whole into a compact mass. They abound in cold and temperate climates in boggy places, furnishing an article of food to animals, and even to man in northern regions.

**Affinities, &c.**—The Musci and Hepaticæ form together a very natural group, with no near allies.

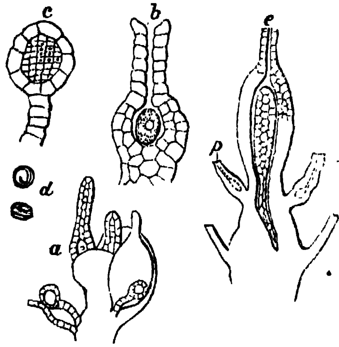
**Distribution, Qualities, &c.**—The Musci are developed over the whole globe, mostly in the moister regions. The Bog-mosses are useful in the formation of peat, and hence indirectly of coal, and in other ways. With this exception, neither Musci nor Hepaticæ have any known use.

## Series 2. HEPATICÆ, or Liverworts.

*Sexual Generation*: Minute creeping plants, with small cellular imbricate distichous leaves, often with a row of imperfect leaves, *amphigasters* (fig. 12, *e*) on the under side, or the whole plant thalloid, forming a leaf-like lobed mass. The antherids and archegones are borne in the axils of ordinary leaves or in depressions in the surface of the thalloid plate, or are elevated on special umbrella-shaped male and female *receptacles*. Sporanges on thread-like stalks (*setæ*), destitute of a columel, except in *Anthoceros*, splitting when ripe in various ways to liberate spores usually mixed with *elaters*.

The *antherids* are elliptical or globular sacs (fig. 11, *c*) formed of a single layer of cells; they are found imbedded in the thalloid stem of *Riccia*, *Pellia*, &c., or in the substance of the (male) receptacles of *Marchantia*, or on stalks arising from the frondose stem in *Fossombronia*, and in the axils of the leaves in the foliose kinds of *Jungermanniaceæ* (fig. 11, *a*). The interior of the sac is filled with minute roundish cells, at first coherent, but ultimately free. These are the mother-cells of the antherozoids, which escape by the rupture of the sac of the antherid, and each of them emits a 2-ciliated spiral antherozoid (fig. 11, *d*). The archegones closely resemble those of Mosses.

Fig. 11.




Antherids and archegones of Hepaticæ:—*a*, vertical section of the inflorescence of *Radula complanata*, with young (axillary) antherids and (terminal) archegones, magn. 50 diam.; *b*, vertical section of an archegone, with oosphere, of *Jungermannia divaricata*, magn. 250 diam; *c*, immature antherid of *Radula complanata* (vert. section), magn. 250 diam.; *d*, antherozoids; *e*, immature sporogone, with surrounding epigone and two abortive archegones (*pp*), of *Radula complanata* (vert. section), magn. 100 diam.

**Classification.**—The Hepaticæ present great diversity of structure in their vegetative organs, and clearly mark the point of transition from the Thallophytes to the Cormophytes. They may be divided into five Orders as follows:—

1. JUNGERMANNIACEÆ. Cormophytes (rarely thalloid) with slender branching stems; branches flattened; leaves distichous (fig. 12, B, *d*) or tristichous, two rows on the upper surface and one of *amphigasters* on the lower (fig. 12, *e*). Antherids and archegones produced on stems usually in the axils of the leaves in the foliose genera, on the dorsal side of the shoot in the thalloid genera; *sporogones* surrounded at the base by a whorl of modified *perigonial* and *perichætial* leaves, and by a *vaginule* or *epigone* (fig. 12, B, *a*), which consists of the entire sac of the archegone without any calypter; sporanges stalked, splitting when ripe into four teeth (fig. 12, *b*), which liberate the spores and *elaters*, *c*; elaters of single long fusiform thin-walled cells with a spiral band in the interior.

2. MARCHANTIACEÆ. Plants small, green, thalloid; stems lobed, dichotomously branched, leaf-like, of many layers of cells, rooting by means of rhizoids, midrib indistinct; *archegones* borne on

the under surface of stalked cap-like lobed bodies proceeding from the sinuses of the frond; antherids borne on the upper side of the club-shaped male receptacles; the fertilized archegones mature into sporanges (fig. 13, *b*), bursting at the apex into four or eight teeth, or splitting transversely or irregularly; capsule with elaters.

The Marchantiaceæ produce cellular bulbils or gemmæ, which in *Marchantia* and *Lunularia* are developed in special cup-like or crescent-shaped receptacles on the upper side of the thallus. They are characterized by bearing stomates of a remarkable and complicated structure.

Fig. 12.

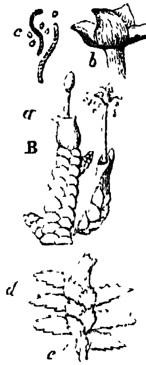



Fig. 13

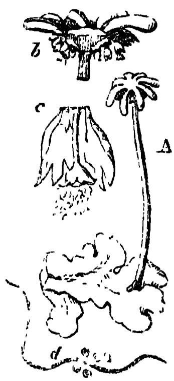



Fig. 12. Structure of Jungermanniaceæ.—B. *Radula complanata* with an unopened and a burst sporange; *a*, the vaginule; *b*, the burst sporange, magnified; *c*, spores and elaters; *d*, fragment of the leafy stem of *Jungermannia umbrosa*, showing the distichous arrangement of the leaves, and the amphigasters (*e*).

Fig. 13. Structure of Marchantiaceæ:—A. *Marchantia polymorpha*, bearing a female receptacle; *b*, vertical section of the receptacle, showing the sporanges on its under surface; *c*, sporange bursting, with its vaginule and perigone laid open; *d*, spores and elater, highly magnified.

3. RICCIACEÆ. Minute aquatic plants; stem thalloid, leaf-like; sporogones borne on or in the upper surface of the stem, destitute of involucre and without elaters, the spores being set free by the decay of the surrounding tissues. Antherids and archegones imbedded in the substance of the thalloid stem.

4. The MONOCLEACEÆ form a transitional link between the Jungermanniaceæ and Anthocerotaceæ. The sexual generation is either foliose or thalloid; the sporogone elongated, dehiscing longitudinally.

5. ANTHOCEROTACEÆ. Thallus flat, irregularly branched; sexual organs not surrounded by a perigone; antherids and archegones produced in cavities of the thalloid stem; sporange pod-like, springing from the archegone, with a central columel, splitting when ripe by two valves, and liberating spores and imperfect elaters without any spiral band.

**Distribution, &c.**—The Hepaticæ are abundant in damp sites in all parts of the world. They have no economic application.

## Class III. *Charales.*

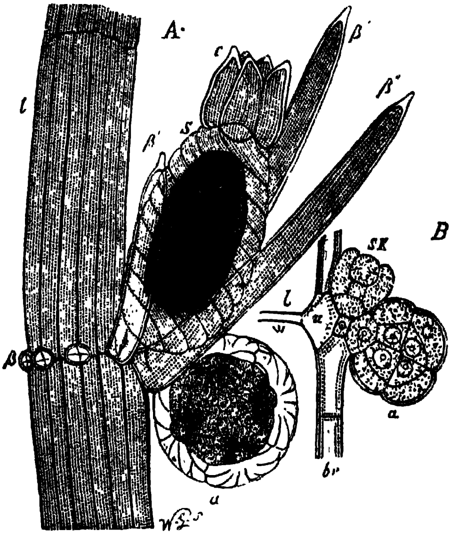
Water plants having verticillately branched stems, rooting more or less at the joints; the stems either simple tubes, or with the central tube clothed by a cortical layer of smaller tubes which grow over the internodes from the top and bottom, and meet so as to envelope it. Reproductive organs on the whorls of branches, female and male, comparatively large and distinctly visible:—*archegones*, axillary oval bodies, consisting of a central cell with a cortex of spirally wound tubes ending in a crown of teeth above; *antherids* globular, bright red, sessile on the branches, bursting when mature into 8 triangular valves, the centre of each valve bearing a stalk whence arise segmented confervoid filaments, each segment of which gives birth to a 2-ciliated antherozoid. The fertilized archegones produce new plants, without any distinct alternation of generations.

**Structure and Life-history.**—This Class contains but one Order, Characeæ, with two principal genera. The structure of the vegetative organs varies with the genus. In *Nitella* each internode consists of only a single elongated cell; while in most species of *Chara* there is a central or axial cell, surrounded in a spiral manner by other cells forming the *cortex*. The structure of the branches, which are always arranged in whorls, is the same as that of the main stem: and they may themselves bear secondary similar whorls. In *Chara* each node consists of a transverse plate of small cells resembling those of the cortical layer, and separating the internodal cells from one another. At each node a tube descends from each leaf, which meets, at the middle of the internode, a corresponding ascending tube. From the nodes other smaller foliar structures arise, which are regarded by some as stipules. The apex of the stem forms a compact terminal bud, with very short internodes, which become gradually longer at a greater distance from the apex. The formation of new nodes and internodes takes place immediately beneath this terminal bud. The Characeæ have no true roots; but the stems are attached to the ground by *rhizoids*. Many species are freely propagated in a non-sexual manner by means of detached *bulbils*, and in other ways.

The reproductive organs are very distinctly characterized, and are borne in a conspicuous external position. The two kinds, male and female,

sometimes called respectively the "globule" and the "nucule," occur either together on the same branch of the plant, on distinct branches, or on separate plants.

Fig. 14.

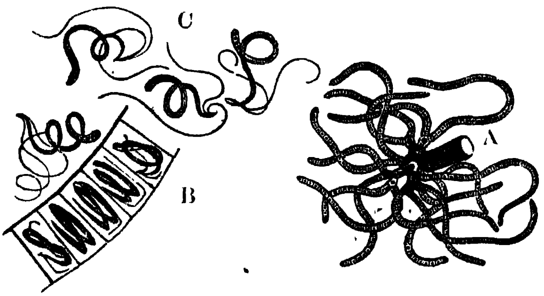



*Chara fragilis.*—A. Portion of branch *a*, adult antherid; *S*, archegone, *c*, its crown of teeth; *β β''*, sterile branchlets × 30. *B* *a*, antherid in course of formation: *sk*, young archegone, *w*, nodal cell; *v*, basal cell between the base of the antherid and of the nodal cell, *br*, cells of branchlet covered with cortex · × 350. (From Sachs.)

The *antherid* (fig. 14, *a*) is a spherical case composed of eight cortical cells, called *shields*; all these have red or orange contents, imparting a colour to the antherid. From the centre of each shield projects inward an oblong cell, the *manubrium* (fig. 15, A); at the extremity of each manubrium is a roundish hyaline cell, the *head* or *capitule*; and each of these bears six smaller *secondary heads* or *capitules*. These eight cells meet in the centre together with the apex of a flask-shaped cell which enters the antherid at its base, forming the *pedicel* by which it is attached to the branch. From each of the secondary capitules grow four long whip-shaped segmented filaments, composed of from 100 to 200 cells each. When the antherid is mature, its valves separate, each being a tuft of the segmented filaments. The cells forming the segments of these filaments, which are therefore from 20,000 to 40,000 in number in each antherid, are then seen each to contain a minute spirally coiled thread (fig. 15, B), which makes its way out as a 2-ciliated actively moving *antherozoid*, resembling those of Mosses.

The *archegone* (fig. 14, *S*), which is green, consists essentially of a large oval central cell, surrounded by a double coat, and, outside this, by five spirally coiled and intimately connected cortical tubes. These five spiral tubes terminate at the summit in five (or ten) teeth; and these teeth eventually separate from each other, leaving a free passage down the centre to the wall of the central cell. The antherozoids from the antherid

Fig. 15.




*Nitella flexilis.*—A, manubrium of antherid, with numerous filaments in which the antherozoids are developed; B, portion of filament, very highly magnified; C, antherozoids.

pass into the canal between the crown of teeth of the archegone, and fertilize the *oosphere* in the central cell. The product of the fertilized central cell or *oosperm* becomes the first cell of the new plant. After fertilization the archegone drops off from the parent, passes through a stage of rest, and in the following season germinates into a new plant, with the intervention (in the case of *Chara*) of a body consisting of a single row of cells, sometimes regarded as a prothallium.

**Affinities.**—In their mode of reproduction, the Characeæ present most resemblance to the Muscineæ, but are distinguished from all other Cormophytes by the absence of non-sexually produced spores, and the complete or nearly complete suppression of any alternation of generations. By some authors they are regarded as a family of Algæ; but they differ widely from all Algæ in being true Cormophytes and in their mode of reproduction.

**Distribution, Qualities, &c.**—The Characeæ or "Brittleworts" grow in stagnant water, and many of them acquire a dull aspect and brittle texture from becoming encrusted with carbonate of lime, precipitated from calcareous matter in the water, but often deficient in cultivated specimens. The unencrusted kinds, the simple tubes of *Nitella*, and the young shoots generally, are well known as objects displaying in a beautiful manner the rotation of protoplasm. The abundant protoplasmic cell-contents cause these plants to give off a very offensive odour when decaying. The species occur all over the world, most commonly in temperate climates. They have no known uses, and are regarded as noxious from their smell when undergoing decomposition.

## SUBDIVISION II. THALLOPHYTES.

Cryptogamic plants provided with a thallus which has no special ascending or descending axis, nor contrast of axis and appendages. Non-sexual propagation by means of spores produced in parent-cells, either forming part of the thallus, or growing upon the surface of definite parts of it. Spores motionless, or motile (*zoospores* or *swarm-spores*), and then resembling antherozoids, though truly non-sexual, germinating at once without producing a prothallium. Sexual reproduction not known in all instances; it varies greatly in the different classes, but the antherozoids are never spiral.

The vegetative structure of Thallophytes, which forms their principal bond of connexion one with another, and their most striking character of distinction from the higher plants, presents a great variety of conditions. The *thallus* presents no contrast of parts analogous to that between the axis (stem) and the appendages (leaves and their modifications), which exists in the higher plants; hence they are necessarily devoid of true buds. A special regularity, however, and a determinate direction of growth, are manifested more or less clearly in all cases, giving definite and characteristic forms to the thallus—cellular, and never forming a tissue in the true sense of the term; though in some of the higher groups it assumes a structure approximating to true tissue, known as *pseudo-parenchyme*, and even presents resemblances to cortex and epiderm.

The classification of Thallophytes is attended with great difficulty in the present state of our knowledge. It has been proposed to abolish the old division into Algæ and Fungi in favour of one dependent entirely on the mode of sexual reproduction; but as this is still but imperfectly understood or is entirely unknown in some groups, such a classification can be provisional only, and seems at least to be premature. We propose therefore to retain the old division (which is an extremely convenient one to the beginner) with some modification, and to divide the Thallophytes into three primary classes, as follows:—

Class 4. *ALGÆ.*—Multicellular or rarely unicellular organisms; most of which (if not all) display some kind of sexual reproduction; living in water or damp places exposed to light, and always containing chlorophyll, and therefore capable of independent vegetation by decomposing the carbonic acid of the air; rarely parasitic.

Class 5. *FUNGI.*—Multicellular organisms, most of which display some kind of sexual reproduction; never containing chlorophyll, and therefore incapable of independent vegetation by decomposing the carbonic acid of the air; always parasitic or saprophytic; sometimes growing in the dark.

Class 6. *PROTOPHYTES.*—Unicellular organisms, with no known mode of sexual reproduction; containing chlorophyll or not.

## Class IV. *Algæ.*

Cryptogams living in water or damp places exposed to light, extremely variable in size, form, colour, and texture, free or attached by root-like organs; sometimes unicellular, more often consisting of an unbranched filament of cells, or having a branched pseudo-stem and leaf-like appendages, sometimes of large size, but exclusively cellular in structure, and destitute of stomates. Propagated non-sexually by cell-division, or by the formation of *zoospores*, or of motionless spores which are then usually formed in groups of fours, *tetraspores*, within a *tetrasporange*. Sexual reproduction effected by antherozoids emitted from antherids, and female cells or oospheres, produced either on the same plant (monœcious) or on different ones (diœcious).

The most familiar examples of this Class are the Seaweeds; but it also includes a great number of plants found in fresh water and in damp situations, many of which are microscopic. The modes of both sexual and non-sexual multiplication present such great variety that they are best described under the separate groups or families.

Algæ are conveniently divided into three Subclasses, *Carpophyceæ*, *Oophyceæ*, and *Zygophyceæ*, dependent on differences in the mode of sexual reproduction.

### Subclass i. **Carpophyceæ.**

The Carpophyceæ are distinguished from the rest of the Algæ by the formation of a highly organized body, the *cystocarp*, as the result of impregnation. The female organ, which is composed of one or more cells, is known as the *carpogone*; the male fertilizing element is either a motile *antherozoid* or immotile *pollinoid*. Except in the simplest forms, other cells besides the actual male and female cells take an indirect part in the process of impregnation, and enter into the composition of the cystocarp, in which the embryo or *carposperm* is enclosed by a sterile envelope, which serves either simply for protection or for nourishment.

The Carpophyceæ are classified under two Series:—

#### Series 1. Florideæ.

Marine (rarely freshwater) Algæ, mostly of a red-purple, rarely olive or brownish colour, with a thallus either foliaceous or of branched filaments, sometimes encrusted with carbonate of lime. The sexual mode of reproduction consists in the impregnation of the female cell or oosphere by a motionless *pollinoid*, which is

passively carried through the water to the apex of a long hair-like tube, the *trichogyne*, a prolongation of the cell which contains the oosphere. The fertilized oosphere or *carposperm* is contained within a more or less complicated structure, the *cystocarp* or sporocarp. Non-sexual propagation also takes place by *tetraspores*, collections of four spores formed in special parent-cells (*tetrasporanges*) in similar situations to the cystocarps.

**Structure and Life-history.**—The Florideæ or Red Seaweeds exhibit almost every possible form between that of the branched filamentous thallus and that of a highly compound or dissected leaf (fig. 16) or a

Fig. 16.


Structure of Florideæ:—A. Part of a thallus or frond of *Laurencia pinnatifida*. B. A magnified fragment of a lobe with stichids containing tetraspores; *c*, a more magnified figure. D. Lobe of the frond bearing cystocarps; *d*, the carposperms. E. Carposperms from the same, more magnified. F. Lobe of a frond bearing antherids, *a*.

shrub-like collection of firm branches; and, moreover, the texture of the thallus varies from a single layer of cells to a cartilaginous or even horny substance, caused by greater development of the cellular system, which, in the higher kinds exhibits a rudimentary distinction between cortical or epidermal layer and internal spongy pseudo-parenchyme. It is, however, never a tissue in the true sense of the term. The thallus or frond of the higher forms is termed *monosiphonous* or *polysiphonous* according as it consists of a single or of several parallel filaments of cells. The Melobesiaceæ are small flat incrustations on marine rocks. The Corallines acquire a stony character from the deposition of carbonate of lime in their cellular tissue. The red colouring-matter, known as *rhodospermin*,

is soluble in cold water, and exhibits beautiful fluorescence. It completely conceals the colour of the chlorophyll which the Florideæ always contain.

The only mode of non-sexual propagation in the majority of Florideæ is by means of motionless *tetraspores*, formed in fours (rarely in pairs or eights) in special receptacles or *tetrasporanges*, which again are often formed on metamorphosed branches of the frond known as *stichids*. Propagation by budding takes place in a very few Florideæ. Sexual and non-sexual organs are very rarely found on the same branch.

The sexual organs vary very greatly in their degree of complexity. The antherids are sometimes isolated terminal cells of special branches, each producing only a single pollinoid; they are more often found in densely packed groups, either on the surface or imbedded in the tissue of the frond. The pollinoids differ from the antherozoids of other Cryptogams in having no vibratile cilia, and consequently no power of "swarming." They are roundish masses of protoplasm, and are moved along passively by currents of water. In the Nemaliaceæ the carpogone consists of a single cell prolonged at the apex into a trichogyne. In the more highly developed forms it is a multicellular structure, a lateral row of cells of which, the *trichophore*, bears the *trichogyne*. The oospheres are produced in other cells lying in the neighbourhood of the trichophore. In the most complex forms of all, such as *Dudresnaya*, the cystocarps are even formed on other branches than those which produce the trichophore; and a single trichogyne may assist in the production of a number of cystocarps. Impregnation always takes place by a pollinoid becoming attached to the apex of the trichogyne; at that spot the cell-wall appears to become absorbed, and the contents of the pollinoid pass into the trichogyne. A still more complicated process has recently been described in the case of some Florideæ, consisting in a double process of impregnation—first, of the oosphere within the carpogone by a pollinoid; secondly, of one or more "auxiliary cells" by the carposperm or fertilized contents of the carpogone, the fertilized auxiliary cell finally developing into the cystocarp. The *cystocarp* may consist of a few rows of cells, imbedded in jelly, as in the Nemaliaceæ, when it is known as a "glomerule," or it may be enclosed in an envelope of thick-walled cells called the *pericarp*. The carposperms are usually more or less imbedded in jelly within the cystocarp; they are either solitary or collected into a larger or smaller mass, which is then known as a "nucleus." Florideæ are either monœcious or diœcious. A very large number of terms has been applied by different writers to the sexual organs of Florideæ either before or after fertilization, as "favella," "favellidium," "coccidium," "ceramidium," &c.

**Classification.**—Much doubt still invests many points of structure in the Florideæ, and the following distribution into Orders will probably have to be modified in some respects with increased knowledge:—

Cystocarps invested by a pericarp.
  Carposperms solitary or in rows, at the ends of tufts of branches within the cystocarp.
    Thallus encrusted with carbonate of lime; cystocarps imbedded.
      CORALLINACEÆ.

Thallus soft, not encrusted.
Cystocarps external; carposperms pear- or club-shaped. RHODOMELACEÆ.
Cystocarps imbedded, or only partially exposed; carposperms round.
Thallus erect, cylindrical; carposperms in moniliform rows. SPHÆROCOCCACEÆ.
Thallus erect, cylindrical; carposperms solitary at the ends of filaments.................... GELIDIACEÆ.
Thallus flat or spherical ........ SQUAMARIACEÆ.

Carposperms imbedded in jelly, forming a "nucleus."
Several nuclei in a cystocarp, each apparently imbedded in jelly.
Fertile filaments branched, forming the carposperms by division thallus foliaceous .............. RHODYMENIACEÆ.
Fertile filaments similar; thallus tubular. DUMONTIACEÆ.
Each nucleus formed directly out of a single cell. GIGARTINACEÆ.
Only one nucleus in each cystocarp .. CRYPTONEMACEÆ.

Cystocarps not invested by a pericarp, forming glomerules.
Glomerules external.
Glomerules composed of irregularly arranged carposperms; tetraspores present .................. CERAMIACEÆ.
The external cells only of the glomerules forming carposperms; tetraspores wanting .............. NEMALIACEÆ.
Glomerules within the tubular thallus .. LEMANEACEÆ.

No cystocarps; thallus of a single filament or plate of cells. PORPHYRACEÆ.

**Distribution.**—The Red Seaweeds are generally diffused, but diminish from warm temperate latitudes both to the equator and the poles. They occur in deeper water than the Olive Seaweeds, and below tide-marks, flourishing best in quiet bays. A few genera, as *Hildenbrandtia, Batrachospermum*, &c., grow in fresh water.

**Qualities and Uses.**—The abundant gelatinous or horny substance of the thallus of many kinds, composed of a modification of cellulose related to gum and starch, renders them nutritious: *Chondrus crispus* is the "Carrageen" or Irish Moss; *Rhodymenia palmata*, *Iridæa edulis*, and other plants of the family yield a similar excellent jelly when boiled. *Plocaria tenax* is largely used by the Chinese for making glue. Some have pungent qualities, as *Laurencia pinnatifida*, called "pepper-dulse." *Plocaria Helminthochorton*, Corsican Moss, has the reputation of being anthelmintic. *Porphyra* is the "red laver" of commerce. The *Corallinaceæ*, including common Corallines (*Corallina officinalis*), and the "Nullipores" (*Melobesia*) bear some resemblance to true corals, on account of their complete interpenetration by carbonate of lime, giving them a brittle and sometimes stony character.

## Series 2. Coleochætaceæ.

Small green freshwater Algæ, some of the cells of which are prolonged into long hairs. The oospheres are fertilized by motile antherozoids, and the carpogone afterwards becomes enclosed in a layer of cortical cells, forming a *cystocarp*. Non-sexual propagation by motile zoospores.

**Structure and Life-history.**—The Coleochætaceæ form small green disk-like or hemispherical patches on submerged water-plants, the sides of aquaria, &c., and derive their name from the prolongation of certain cells into a bristle fixed in a narrow sheath. The branches of the thallus are usually arranged with great symmetry. In their reproduction they display a kind of alternation of generations. The carposperms on germination produce only non-sexual plants, or such as form zoospores; the zoospores giving rise to a sexual generation only after several non-sexual generations. The carpogone contains only a single carposperm, which, on germination, breaks up into a number of *carpospores*. Zoospores may arise from all the vegetative cells of the thallus.

**Affinities, &c.**—*Coleochæte* is clearly allied to the lower forms of the Florideæ, like *Nemaleon*. Through *Bulbochæte* it also presents an affinity to the Œdogoniaceæ. In its vegetative structure it resembles the Palmellaceæ.

## Subclass ii. **Oophyceæ.**

The Oophyceæ are distinguished from the Carpophyceæ by the simpler structure of the fertilized female organ, and the simpler mode of impregnation. The two reproductive cells are still essentially different; the male cell is always a motile antherozoid; the *oosperm* or fertilized oosphere is developed within a simple cell, the *oogone*. They comprise the following Series:—Fucaceæ, Phæosporeæ, Œdogoniaceæ, Vaucheriaceæ, and Volvocineæ.

## Series 1. Fucaceæ.

Olive-coloured Seaweeds of gelatinous, cartilaginous, or horny texture, with a foliaceous or shrub-like or cord-like thallus, attaching itself to rocks by a simple or lobed and ramified discoid base; fructification in *receptacles* formed out of lobes of the fronds, the external surface of which is pierced with orifices leading to chambers (*conceptacles*) lined with filaments intermixed with *oogones* containing *oospheres*, or with *antherids*, or with both of these; the olive-coloured oospheres are contained 4 or 8 in an oogone, from which they escape when mature, and are fertilized by the active

2-ciliated *antherozoids* after they are detached from the parent-plant.

**Structure and Life-history.**—The Olive-coloured Seaweeds, including the Fucaceæ and the Phæosporeæ, exhibit a gradation in the degree of development of the thallus similar to that of the Florideæ. The lower

Fig. 17.

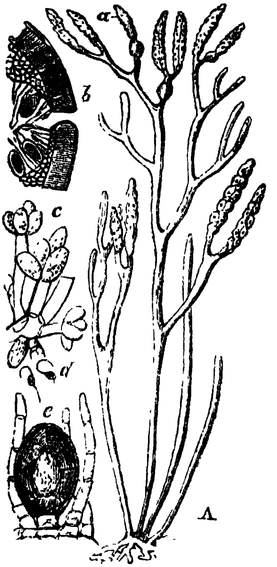



Fig. 18.

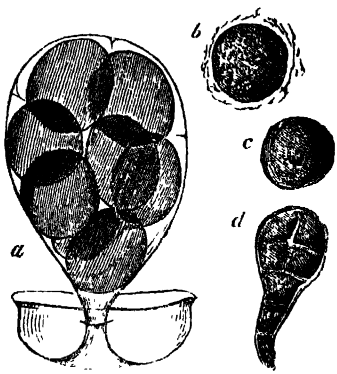



Fig. 17. Structure of Fucaceæ:—A. *Halidrys siliquosa*, half the nat. size: *a*, pods or receptacles; *b*. section through receptacles, showing the mouth of a conceptacle, the cavity of which is lined by antherids (*c*) producing antherozoids (*d*) and by oogones (*e*).

Fig. 18. Development and fertilization of oospheres of *Fucus vesiculosus*: *a*, inner oogone bursting from the outer sac and about to liberate the oospheres. *b*, a free oosphere (devoid of cellulose coat) surrounded by antherozoids; *c*, impregnated oosperm with a cellulose coat; *d*, the same germinating. Magn 160 diameters.

forms of Phæosporeæ present tufts of branched filaments; the higher forms of these, and the Fucaceæ, have thick leaf-like or stem-like fronds of firm texture and sometimes enormous dimensions; many of them have a shrubby habit of growth, and attach themselves to stones &c. by discoid or branched expansions from the base, resembling superficially the roots of the higher plants, but having no similar function or anatomical character. The thallus of the larger forms is highly developed, having a distinct cortical layer; but the structure is strictly cellular, without a trace of woody fibre or vascular elements. The outer layers of cells commonly swell up greatly with fresh water, becoming slimy, owing to the conversion of the cellulose into mucilage. The colour is here usually

olive, brown, or some dull tint of green-brown, caused by a special pigment, known as *fucoxanthin*, which completely conceals the colour of the chlorophyll, and which is soluble in cold water. The fronds are often buoyed up by large air-vessels hollowed out of the tissue of the frond, as in our common "bladder-wrack," *Fucus vesiculosus*, or elevated above its surface, as the "berries" of the "gulf-weed," *Sargassum bacciferum*.

The sexual reproductive organs are limited to different parts of the thallus. In *Fucus* and *Halidrys* (fig. 17) they are formed at the ends of the lobes of the thallus. Externally the lobe (or *receptacle*) presents a thickened appearance, marked with numerous distinct orifices; these orifices lead to chambers imbedded in the thickness of the thallus (the *conceptacles*, *b*), bearing on their walls cellular sacs of two kinds—one, the larger (*oogones*, *e*), containing the oospheres, usually 2, 4, or 8 in number, the smaller (*antherids*, *c*) containing *antherozoids* (*d*); both kinds of sacs burst and discharge their contents when ripe, and the oospheres are fertilized and encysted while still in the water. The female conceptacles are originally lined with filaments, some of which swell up and develop into the oogones; others remain sterile and do not undergo metamorphosis into oogones; they are known as *paraphyses*. Sometimes the antherids are present in the same conceptacles as the oogones; or they are borne on a separate plant (diœcious). The antherids consist of ovoid cells, borne on branched threads and containing a whitish mass, interspersed throughout which are a number of red granules. No non-sexual mode of propagation is known in the Fucaceæ.

**Distribution, Uses, &c.**—The Fucaceæ are entirely marine, and are distributed over the whole globe, but are most abundant in colder seas, where, with the Phæosporeæ, they form the mass of the marine vegetation. They become extremely slimy when exposed to damp air, from the conversion into mucilage of the outer layer of cells. From the great quantity of ash which they contain, they are largely used for manuring the land; the burning of "kelp," and preparation from it of the alkalies was at one time an important industry in Northern Europe; and it is still the chief source of iodine. The gelatinous substance of the fronds is occasionally used as food by men or animals. The "Sargasso-sea" in the Gulf of Florida is covered by an immense tract of detached floating branches of the "gulf-weed," *Sargassum bacciferum*.

## Series 2. PHÆOSPOREÆ.

Olive-coloured or brown Seaweeds with a foliaceous, shrubby, or branched filamentous thallus; reproduced by *zoospores*, having two cilia, one directed forwards, the other backwards, formed in club-shaped cells or multicellular filaments, collected in more or less definite groups on the cortical layer of the thallus of the larger kinds, in lateral tufts or terminal on the branched filamentous kinds. Sexual reproduction unknown or consisting in a conjugation of zoogametes.

**Structure and Life-history.**—The lowest forms of the Phæosporeæ consist of a single filament of cells; while the genera with highly developed thallus approximate to the Fucaceæ, but no organs resembling the oogones of those seaweeds are known. The ordinary organs of propagation are non-sexual zoospores, which germinate and produce new plants directly; the cilia are two in number, unequal in size, and take reverse directions as they leave the body of the zoospore; they resemble the antherozoids of *Fucus*. The size and number of the zoospores are not constantly the same in the same plant; and the organs producing the zoospores are sometimes large club-shaped sacs or chambered filaments, the number of zoospores in a cell being either definite or indefinitely great, on account of more advanced segmentation of the contents. The colouring-matter appears to be the same as that of the Fucaceæ.

The zoosporanges themselves are either unilocular or multilocular. In *Cutleria* and *Ectocarpus* recent observations show that the zoospores unite by conjugation, and these bodies, though apparently similar to one another, have therefore a rudimentary sexual character, and are, in reality, *zoogametes*. In some genera, as *Sphacelaria*, organs resembling antherids, but apparently functionless, have also been observed. In *Sphacelaria* a mode of propagation by buds or gemmæ is known.

**Classification.**—The Phæosporeæ have been divided into the following Orders:—

Thallus foliaceous or fruticose.
  Thallus differentiated into a medulla with elongated, and a cortex with short cells .................... CHORDARIACEÆ.
  Thallus entirely parenchymatous.
    Sporanges in roundish or linear groups over the whole surface of the thallus ..................... DICTYOTACEÆ.
    Sporanges in indefinite groups, or dispersed over the whole surface of the thallus ................... LAMINARIACEÆ.
    Sporanges on special branches, often of peculiar form. SPOROCHNOIDEÆ.
Thallus of one or several filaments of cells of parenchymatous structure. SPHACELARIACEÆ.
Thallus of a single branched filament of cells. ECTOCARPACEÆ.

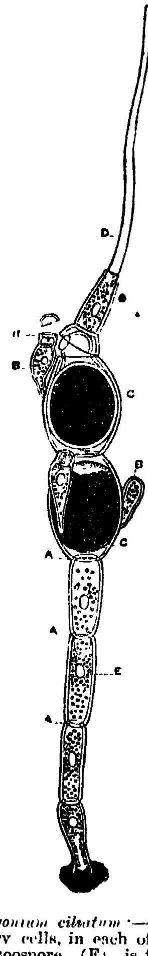
**Affinities, &c.**—In their vegetative structure the larger Phæosporeæ very closely resemble the Fucaceæ; but too little is known of their mode of reproduction to determine whether they constitute a natural group, or whether they must be divided into widely distinct families. The conjugation of zoospores in the Cutleriaceæ and Ectocarpaceæ indicates an alliance with the Confervaceæ, and points to a connecting link between the Oophyceæ and the Zygophyceæ.

**Distribution and Qualities.**—Much the same as in Fucaceæ. *Laminaria digitata* and *saccharina* are eaten (under the name of Tangle) on the coasts of the North of Europe, as also is *Alaria esculenta*. Some tropical genera, as *Macrocystis* and *Alaria*, attain a gigantic size, with rudimentary differentiation of the frond into stem, leaves, and rhizoids. The hollow stems are used by the natives for a variety of purposes.

## Series 3. ŒDOGONIACEÆ.

Green freshwater Algæ, consisting of unbranched (or branched?) filaments, the cells of which are marked by a peculiar formation of caps at one end; reproduced sexually by antherids and oogones; non-sexually by large zoospores formed singly in a cell, or by peculiar very small zoospores, which attach themselves to the parent plant.

Fig. 19.




*Œdogonium ciliatum*.—A, ordinary cells, in each of which a zoospore (E) is formed; C, C, oogones; B, B, androspores, one bearing at *a* an antherid, the lid of which is detached; D, extremity of the plant.

**Structure and Life-history.**—The filaments of *Œdogonium*, several species of which are common in fresh water, are fixed by an organ of attachment, known as a "rhizoid," to solid bodies or submerged plants. The cells display a remarkable appearance from the phenomenon known as "intercalary surface-growth," in which a number of annular deposits of cellulose are formed in succession below the upper septum, giving the appearance of a series of caps. The sexual reproduction presents no special features; the species are either monœcious or diœcious. The formation of the ordinary non-sexual zoospores is a typical example of the process known as "rejuvenescence" of a cell, the entire protoplasm of the parent-cell being transformed into a primordial cell, which subsequently invests itself with a new cell-wall, and forms the starting-point of the life of a new individual. The zoospores are furnished with a tuft of cilia at one end, and are among the largest known in the vegetable kingdom. They are produced in the ordinary sexual, and especially in the female, plants. In addition to these, peculiar zoospores, known as *androspores*, are produced in special cells similar to those which give birth to the antherozoids. They resemble the ordinary zoospores in every respect, except their much smaller size; after swarming they fix themselves to a definite spot of the female plant, on or near the oogone, where they germinate, producing very small male plants, the "dwarf males" or *micrandres*, each consisting usually of only a single antheridial cell, which gives birth to antherozoids that impregnate the oospheres in the ordinary way.

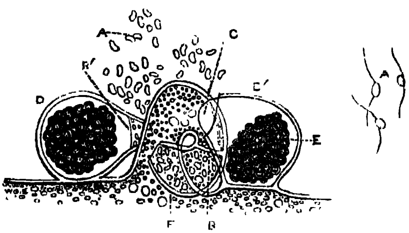
In *Bulbochæte*, which presents a transition to the Coleochætaceæ, the filaments are branched, and each branch terminates in an elongated hair.

SPHÆROPLEA *annulina* is a freshwater filamentous alga, composed of rows of cylindrical cells provided with remarkable thick bands of cellulose, in which fertilization of the oogones by antherozoids has been observed. In some of its cells the contents are converted into a number of oospheres, in others of the same filament into numerous antherozoids. When mature, orifices are formed in walls of the cells of both kinds; the antherozoids escape from their parent-cell, and make their way in through the orifices of the oogones; the oospheres when fertilized produce their cellulose coat and ripen to resting-spores, which are set free by the decay of the parent filaments. On germinating these give rise to a large number of zoospores, and these again to sexual filaments; so that *Sphæroplea* displays a kind of alternation of generations. It is found on flooded fields. Its affinities are somewhat obscure.

## Series 4. VAUCHERIACEÆ or SIPHONEÆ.

Unicellular Algæ, producing two kinds of non-sexual propagating organs—resting-spores and zoospores, as well as male and female reproductive cells. The antherids appear in the form of small horns placed in the proximity of ovoid oogones. These antherids contain numerous extremely minute antherozoids, which escaping fertilize the oogone and determine the formation of an oosperm, which does not germinate immediately, but only after the lapse of some time.

Fig. 20.




*Vaucheria*: A, A, antherozoids, B, C, horn-like antherid, D, D', oogones; E, oosperm.

*Vaucheria* is a genus of filamentous Algæ, growing on damp ground, or in fresh or brackish water, in which the long branched filament consists of a single enormously developed cell, septated only beneath the organs of reproduction. It is propagated non-sexually by zoospores of large size, and entirely surrounded by a beautiful fringe of cilia, discharged

from the thickened end of the filament or of its branches. Non-sexual resting-spores are also formed by rejuvenescence in the ends of particular branches which become shut off by septa. But at certain epochs lateral structures are developed, as branch-cells, which become shut off from the main tube by septa; some of these processes expand into ovate and beaked or bird's-head-shaped bodies, others into short curled filaments or "horns." The former are oogones, the latter antherids. When ripe, the antherids or "horns" discharge their cell-contents in the form of numerous spindle-shaped antherozoids, moving actively by the help of a pair of cilia. Meanwhile an orifice is formed in the beak of the oogone, and some of the antherozoids make their way in, so as to come into direct contact with the oospheres. This phenomenon is followed by the closing-up of the oogone by a membrane, and the conversion of its contents into a fertile oosperm. The species are mostly monœcious. The oosperm on germination produces several generations of non-sexual and then the sexual form. A peculiar form of *Vaucheria*, septated by thick gelatinous walls, has been described as a distinct organism under the name *Gongrosira*.

## Series 5. VOLVOCINEÆ.

Microscopic bodies swimming in fresh water by the aid of cilia arranged in pairs upon the surface of a common semi-gelatinous envelope; each pair of cilia belonging to a green corpuscle resembling a zoospore, imbedded in the periphery of the common envelope. Non-sexual propagation by the development of new colonies within the parent colony, the whole being set free by the solution of the parent envelope, or by the formation of resting-spores; sexual reproduction by the formation of internal oogones and antherids, impregnation taking place within the colony.

**Structure and Life-history.**—*Volvox globator* is a common and most beautiful microscopic object in the standing water of pools, &c. Its appearance is that of a transparent membranous hollow sac studded with green points, while in the interior are seen dense green globes, the original number of which is apparently always eight. The green peripheral corpuscles are each provided with a pair of vibratile cilia, protruding through the envelope, by means of which the organism is driven about with great rapidity. The internal green globes are young individuals, and the organism thus constitutes a colony or *cœnobe*. The male and female reproductive cells, antherids and oogones, are formed in the same colony at different periods. *Volvox* may multiply non-sexually for several successive generations, and these are then succeeded by a sexual mode of reproduction.

**Affinities, &c.**—*Volvox* is nearly allied to the Pandorineæ, but differs in the possession of sexual reproductive cells.

## Subclass iii. **Zygophyceæ.**

In this Subclass the cells which coalesce in the act of reproduction are no longer differentiated, or are only with difficulty distinguished from one another; and this mode of reproduction is known as *conjugation*. The conjugating cells may be either motionless, or may be possessed of vibratile cilia giving them a power of independent motion, and hence indistinguishable from zoospores; they are then known as *zoogametes*.

### * *Conjugating cells not ciliated.*

### Series 1. CONJUGATÆ.

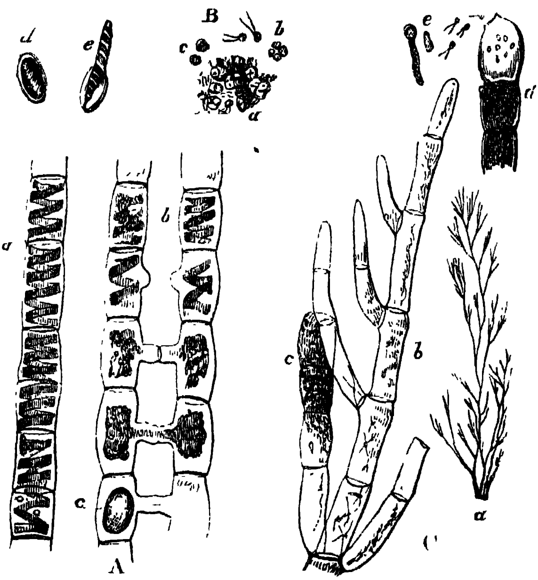
Under this head are included three Orders, viz.:—

ZYGNEMACEÆ.—Unbranched filamentous freshwater Algæ, with the chlorophyll arranged in beautiful spiral bands, stars, plates, or other regular forms. The only mode of reproduction known is by conjugation, two cells belonging to different filaments putting out tubular processes, which finally unite, the protoplasm of one cell either passing through the tube and coalescing with the protoplasm of the other cell, or the contents of both cells uniting in the tube; less often conjugation takes place between two filaments without the formation of connecting tubes, or even between two cells of the same filament. Zoospores unknown in the family.

**Structure and Life-history.**—The Zygnemaceæ are among the commonest and most beautiful of freshwater Algæ. The filaments are usually quite unbranched; the cells often of very large size, displaying an evident nucleus, and with the chlorophyll arranged in spiral bands (*Spirogyra*), two stars (*Zygnema*), or a very thin axile plate (*Mesocarpus*). The reproduction by *conjugation* may be watched with great ease in many species. In *Spirogyra* and *Zygnema*, when conjugation is about to commence, two filaments, lying side by side, exhibit papillary elevations of the cell-walls on the side next their neighbour; these processes elongate until they come into contact; they then adhere, and the septum at the plane of union becomes absorbed, so that the two cells become connected by a tubular process. The contents of the cells meanwhile retract from the wall, the chlorophyll losing its spiral appearance, and become condensed into an ovoid mass; then the whole contents of one cell pass through the connecting tube into the opposite cell. In *Mesocarpus*, the contents of both cells pass into the connecting tube, which expands into a globular cavity in the middle. In either case the contents of the two cells become combined, and they form a globular or oval body known as a *zygosperm*, which possesses two or three firm coats, enters a stage of rest, and remains after the parent filament has decayed away, the green

cell-contents giving place to a brown or red substance. After a time, usually in the spring succeeding the formation of the zygosperm, this germinates, bursting its coats and developing into a new filament like the parent. In other genera, again, as *Gonatonema*, the filaments bend so as to bring a cell of each into contact without any tubular process, their contents then coalescing. Only very slight differences can in any case be detected between the two conjugating cells; in some cases the cells of one filament conjugate with those of several others; but when two filaments conjugate, the zygosperms are invariably formed in one only of the two, indicating a rudimentary sexual differentiation. A process of *lateral conjugation* between two adjacent cells of the same filament is of less common occurrence.

Fig. 21.

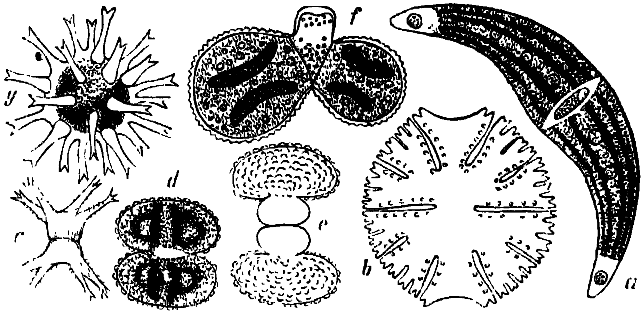



A. Filaments of *Spirogyra*: *a*, in natural condition (magnified 50 diams.); *b*, two filaments conjugating; *c*, a zygosperm; *d*, a free zygosperm; *e*, the same germinating. B. *Protococcus viridis* (magnified 200 diams.) · *a*, a group of cells invested in mucilage; *b*, four cells formed by division of a cell of *a*, and two zoospores escaped from one of the cells, subsequently settling down as resting-cells *c*. C. *Cladophora glomerata*: *a*, filaments (nat. size); *b*, top of a branched filament (magnified); *c*, cells about to form zoospores; *d*, the same, with the zoospores escaping from the uppermost cell; *e*, zoospores germinating into new filaments.

DESMIDIACEÆ.—Unicellular organisms, occurring isolated in fresh water, of symmetrical outline, and containing chlorophyll arranged in symmetrical bands or plates; often endowed with spontaneous motion. Reproduction by division or by conjugation.

**Structure and Life-history.**—The Desmids are extremely beautiful microscopic objects, universally present in fresh water, stagnant or running. In most of the genera the cells are quite isolated; but in others, as *Desmidium*, *Hyalotheca*, &c., they are united into long filaments. The ordinary mode of propagation may be well followed in *Cosmarium*. The two somewhat unequal halves of the cell gradually separate from one another, leaving a connecting band, which is ultimately divided midway by a septum; each half of this band gradually assumes the form of a half-cell, forming a new individual together with the half of the parent individual with which it was in connexion. The two new individuals at

Fig. 22.




Various Desmidiaceæ. *a. Closterium moniliforme*, ×200; *b. Micrasterias papillifera*, ×200; *c. Staurastrum paradoxum*, ×300; *d. Cosmarium margaritiferum*, optical section, ×300; *e* The same in the process of subdivision, surface view, × 300; *f. Cosmarium botrytis*, conjugating cells, × 390, *g.* Zygosperm of *Staurastrum spinosum*, × 400.

length separate from one another, and are always somewhat smaller than the parent. This process is from time to time varied by a process of conjugation which reproduces individuals of the original size. At certain stages the cells which appear as if about to divide approach in pairs, and, a fracture of the external cell-membrane having taken place at the usual line of division, the contents of each cell, bounded by the primordial utricle, escape, come into contact with each other, and become confluent into a mass which assumes a rounded form. This round body becomes coated by a cellulose coat, and ultimately by a second, inside the first. Its contents change from a green to a brown or yellowish colour; and the globular cell remains after the two empty parent-cells have decayed. The zygosperms of many species of Desmids are beautifully covered with spines. Among the more abundant and beautiful genera are *Micrasterias*, *Cosmarium*, *Closterium*, *Euastrum*, *Staurastrum*, *Docidium*, &c.

DIATOMACEÆ.—Microscopic unicellular organisms, occurring isolated or in groups in fresh, brackish, or salt water, usually

surrounded by a gelatinous investment, the cells exhibiting more or less regular geometrical outlines; usually containing a brown or olive pigment, and enclosed by a membrane impregnated with silex and separable into valves; often endowed with spontaneous motion. Reproduction by division or by conjugation.

**Structure and Life-history.**—The Diatoms comprise a very large number of species, and occur in large quantities in running and stagnant fresh water, and in the sea, also in moist earth, on the trunks of trees, and in almost all damp situations. From their symmetrical form (composed of two similar half-*frustules*), the variety of their form, and the fineness and regularity of the striations on their thin transparent siliceous coat, they are extremely beautiful microscopic objects. The green colour of the chlorophyll is almost always obscured by a brown colouring substance known as *diatomin*, insoluble in water, and not, or only slightly, fluorescent. Diatoms are either social, occurring united to one another in groups or strings, and attached to some submerged object, often by a long gelatinous stalk, or isolated, when they are endowed with an irregular jorking motion through the water. The cause of this motion has been the subject of great controversy. The statement of some writers that it is due to protoplasmic cilia or "pseudopodes" projecting through minute orifices in the siliceous coat, has not been confirmed by the observation of others; and the most probable explanation is that it is dependent on the contractility of the enclosed protoplasm. Diatoms multiply either by simple division, or by conjugation of the two half-frustules of which each individual is composed. One is slightly larger than the other; this is the older, and fits on to the younger one like the lid on a box. The line of junction of the two valves is known as the girdle or *hoop*. In many Diatoms the central line of each valve is occupied by several prominences known as *nodules*; and the longitudinal line or rib connecting these nodules is the *raphe* or suture. When the cell begins to divide, the two valves separate from one another, the contents divide into two daughter-cells, and new siliceous valves are formed inside the old ones, and necessarily, therefore, smaller than they. The individuals must therefore constantly diminish in size, until the original size is restored by the producttion of an *auxospore*; the contents, leaving the siliceous valves, which fall away from one another, increase either simply by growth or by the coalescence of the contents of two half-frustules. The auxospore finally becomes invested by a new siliceous cell-wall. In some genera a true process of conjugation has been observed, a zygosperm being produced as the result of the coalescence of two different individuals, which have previously become enclosed in a gelatinous envelope.

**Distribution, Uses.**—Diatoms often occur in such immense quantities in fresh water as to form a thick floating scum. They are present in many geological strata, and in such enormous masses as to form thick beds, constituting the substances known as tripoli, emery, &c. In some countries they constitute the edible earths which are made into a meal to take the place of flour. The variety of beautiful symmetrical forms in the diatoms is very great,—boat-shaped in *Navicula* and *Pinnularia*, sigmoid in *Pleurosigma*, circular in *Meridion*, resembling a number of

cards attached to one another in *Diatoma* and *Fragilaria*, wedge-shaped and attached to long stalks in *Gomphonema*, &c. Several species are also valuable to microscopists as test-objects from the regularity and fineness of the markings. Diatoms are also known as *Bacillariaceæ*.

*** Conjugating cells ciliated zoogametes, resembling zoospores.*

### Series 2. ULVACEÆ.

Green freshwater or marine Algæ, in which the thallus consists of a single plate of cells. Reproduction by cell-division or the conjugation of motile ciliated primordial cells.

**Structure and Life-history.**—The thallus of the Ulvaceæ consists of a single layer of cells, or at most two, either expanded in the form of a ribbon-like plate (*Ulva*), or in that of a tube (*Enteromorpha*). Reproduction by ordinary zoospores has been observed in *Ulva*, and by the conjugation of zoogametes in *Enteromorpha*; by the division of cells in a direction parallel to the surface, and the detachment of a projection which develops into a new thallus, in *Monostroma*.

**Affinities, Uses, &c.**—The Ulvaceæ are undoubtedly nearly allied to the Porphyraceæ. *Enteromorpha* is very common in brackish ditches; several species of *Ulva* in the sea. The latter are esculent, and are known as "green laver."

HYDRODICTYON is an extremely beautiful organism found in ditches, and known as the "water-net." The mature plant is a *cœnobe* composed of a great number of cylindrical cells arranged so as to form a sac-like net. Fresh colonies are formed within the parent colony by the endochrome of a cell breaking up into an enormous number of zoospores, which, after "swarming" for a time, come to rest, and unite to form a new colony. Conjugation of similar but smaller motile swarm-cells or zoogametes has also been observed.

PEDIASTRUM is a genus of which several species are common in fresh water. Each cœnobe consists of a number of cells arranged in a single plane to form a symmetrical figure. The mode of reproduction is either non-sexual or by the conjugation of zoogametes.

ULOTHRIX *zonata*, found in rapidly running water, is a deep-green unbranched filament of cells, reproduced by zoospores, or by the conjugation of zoogametes.

### Series 3. CONFERVACEÆ.

Green (rarely coloured) freshwater Algæ, consisting of branched or unbranched filaments densely filled with chlorophyll. Reproduction by zoospores or by the conjugation of zoogametes.

**Structure and Life-history.**—Although some genera of Confervaceæ are among the most abundant of freshwater Algæ, rapidly choking the water with their branched dark-green filaments, their life-history is as yet but imperfectly known. The ordinary mode of propagation is by zoospores produced in large numbers in the ordinary vegetative cells. In a few instances conjugation has been observed of motile ciliated bodies resembling the zoospores in every respect except their much smaller size. *Draparnaldia* is a beautiful minute microscopic organism, with the branches arranged in whorls. In *Chætophora* the filaments are clothed by a gelatinous envelope, and frequently end in a colourless bristle, as they do also in *Draparnaldia*. *Cladophora* (fig. 21 B, p. 53) is an exceedingly common freshwater alga belonging to this family.

**Distribution, &c.**—The Confervaceæ are excessively common in fresh water, especially stagnant, which they quickly choke by their rapid growth.

The TRENTEPOHLIACEÆ or Chroolepideæ comprise a small group of Algæ, sometimes of an orange-red colour, found on damp walls, the trunks of trees, &c., reproduced by the conjugation of zoogametes or by zoospores.

PITHOPHORA is a genus of freshwater Algæ, natives of tropical countries, recently found also in North America, with remarkable barrel-like swellings in the filaments; allied to Confervaceæ.

SIPHONOCLADACEÆ.—Mostly marine Algæ composed of a single much-branched cell. Reproduction by the conjugation of motile ciliated zoogametes.

**Structure, Life-history, &c.**—An Order of very uncertain limits, and nearly allied to the Vaucheriaceæ. They present the remarkable character of extremely elongated branched cells, each of which contains a large number of nuclei. Reproduction by conjugation has been observed only in some of the genera. *Botrydium* goes through a kind of alternation of generations, producing, in addition, ordinary zoospores contained in a *hypnosporange*, which remains dormant for a considerable time before producing zoospores. The thallus of some of the species assumes very beautiful forms, *Acetabularia* resembling a minute hymenomycetous fungus, *Caulerpa* a leafy branch, *Codium* a sponge, &c. They are mostly natives of warm seas, and are frequently strongly encrusted with lime. Gigantic fossil Algæ of similar form have been found in several geological strata.

## Series 4. PANDORINEÆ.

Freshwater organisms, either unicellular or consisting of a number of cells united into a cœnobe by a gelatinous envelope; each cell is provided with a pair of cilia. Reproduction by cell-division or by the conjugation of zoogametes.

**Structure and Life-history.**—The Pandorineæ display considerable affinity to *Volvox*. *Chlamydomonas* consists of a single biciliated primordial cell with an eye-spot and two contractile vacuoles; these break up into similar smaller bodies, which conjugate to produce a new individual. It displays a very close approach to the Infusorial Animalcules. *Pandorina* consists of a colony of sixteen similar cells. *Stephanosphæra* has a globular condition, in which new globular colonies are formed within the parent colony; the whole being endowed with a rotating motion.

## Class V. *Fungi*.

Cryptogams consisting of long thread-like tubular generally branching *hyphæ* or filaments, which may be septated or not, either distinct or interwoven into a mass which is in some cases microscopic in dimensions and in others of considerable size; nourished on organic substances as parasites or as saprophytes, and entirely destitute of chlorophyll or similar pigments. The portion imbedded within the substratum on which the Fungus grows is known as the *mycele*, and the portion which bears the spores as the *hymene*. Reproduction effected by both sexual and non-sexual means.

This Class includes an enormous number of species, varying in size from the comparatively large mushroom or puff-ball to the different kinds of mould, and to still more minute microscopic organisms. There are several kinds of non-sexual propagation, the most common being the formation of special propagative cells or *spores*, which are either detached from the extremities of the hyphæ, or are produced by free cell-formation inside the ordinary cells or special organs, and which are sometimes motile *zoospores*. The mode of sexual reproduction also varies greatly, and is best described under the separate families. The larger Fungi have a great tendency to the production of *sclerotes*, densely interwoven masses of partially lignified hyphæ, which retain for a long period their power of germination. The cells of Fungi are entirely destitute, not only of chlorophyll, but also of starch. The cell-wall is composed of a substance differing somewhat in its properties from ordinary cellulose, since it is not coloured blue by iodine and sulphuric acid; it has been termed *fungus-cellulose*.

A considerable number of Fungi display a marked *alternation of generations*, the cycle of generations being completed by two distinct forms, with totally distinct organs of reproduction, and always growing on different hosts, which would not be recognized as connected with one another if the history of their development had not been followed out. The Lichens also exhibit the most remarkable illustration in the Vegetable Kingdom of the singular phenomenon of *symbiosis* or commensalism.

Fungi may be divided into three or four Subclasses, somewhat corresponding to those of Algæ.

## Subclass i. **Carpomycetes.**

A group of very doubtful value. In one very large division, the Basidiomycetes, no mode of sexual reproduction has as yet been detected with certainty, and they can only be included within it provisionally. In others the so-called "fructification," corresponding to the cystocarp of the Carpophyceæ, is a complicated structure resulting from the action of a male organ or *antherid* on a female organ or *carpogone*. Non-sexual propagation takes place by the separation of motionless spores or *conids*, either externally or internally; zoospores are unknown.

The Carpomycetes are classified under three Series:—

### Series 1. Ascomycetes.

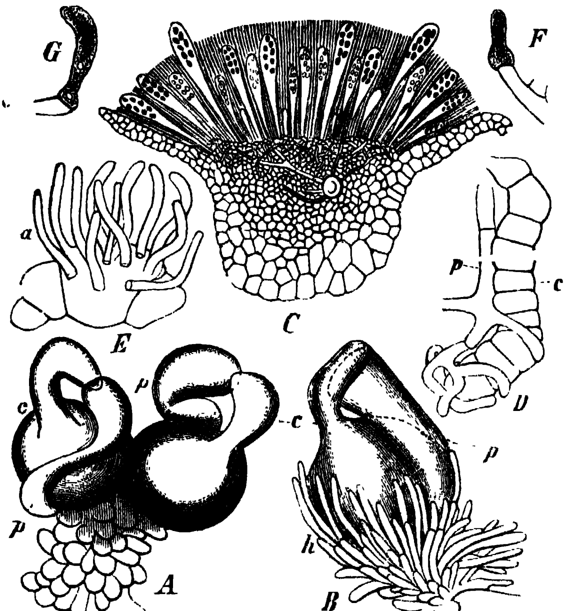
Fungi growing chiefly on the dead parts or remains of plants, more rarely on living plants or organic solutions. The spores are formed in *asci* by free cell-formation, and are distinguished by the name of *ascospores*.

The spores have always a double coat; the outer coat or *exospore* is cuticularized and often rough; the inner coat or *endospore* consists of pure cellulose, and on germination ruptures the exospore, and becomes the first hypha or *germinating filament* of the mycele. The mycele consists of densely branching hyphæ, and develops either within the host or spreads on its surface; it is sometimes short-lived, and sometimes persists for years. In most cases it produces non-sexual propagative organs—*conids* or *stylospores*. The conids are borne on *conidiophores* or special branches of the mycele, and the stylospores are formed in special conceptacles known as *pycnids*. The mycele is extensively reproduced by these non-sexual organs, and in many species they are the only reproductive organs known. In all cases, however, in which the complete life-history has been followed, the same mycele has been found ultimately to produce sexual organs, and, as a result of the fertilization of those, a *fructification*, in the *asci* of which are formed the *ascospores*. This completes the cycle of generations. If the fructification is more or less completely closed, it is known as a *perithece*, if open as an *apothece*. The female organ or *carpogone* frequently possesses a terminal tube or *trichogyne*, through which fertilization takes place. The fertilizing bodies or *pollinoids* are in all cases motionless, and are contained in *antherids*. These were formerly known as "spermatia" and "spermogones" respectively.

The details of the structure and life-history of the Ascomycetes are best described under the following separate Orders:—

DISCOMYCETES.—Fungi living on dead organic bodies, and forming on the branches of the mycele sexual organs—the *carpogone* and the *antherid*. From the fertilized carpogone, or, as it is also called, *ascogone*, arise the asci in which the ascospores are formed. The ascospores germinate and reproduce the mycele. The hymene is superficial, and on it are borne the asci, and usually *paraphyses*, sterile filaments, considered by some authors to be abortive asci.

Fig. 23.




A and B. Sexual organs of *Peziza confluens*, × 380 (Tulasne). C–G. *Ascobolus furfuraceus* (Janczewski). C. Ripe fructification in longitudinal section, × 70. D. Sexual organs, × 490. E. First development of the asci, × 300. F, G. Young tubes? × 490. *c*. Carpogone; *p*, antherid; *a*, young asci; *h*, sterile filaments.

**Structure and Life-history.**—The life-history of *Ascobolus* is typical of the Discomycetes generally. In it the antherid and the carpogone consist each of a series of short crooked cells arising on neighbouring branches of the mycele. The slender cells of the antherid embrace the more remote end of the sausage-shaped carpogone, and in this way fertilization takes place by the passage of protoplasm from the antherid to the carpogone. In consequence of fertilization, one of the cells in the

middle of the carpogone grows larger than the others, and becomes globular in shape; it is distinguished by the name of *ascogone*. This then sends out numerous hyphæ on which are borne the flask-shaped asci, and in them are produced the ascospores, 8 in number. The hyphæ of the mycele on which the sexual organs are borne produce, by repeated cell-division, a dense mass of pseudo-parenchyme, which surrounds the carpogone and forms the sterile part of the fructification. The paraphyses, which are borne on the same hyphæ with the asci, are situated between the latter, and may serve to assist in some way the dehiscence of the asci; they are generally regarded, however, as abortive asci. The whole fructification is cup-shaped. The process of fertilization in *Peziza*, though differing in some respects from that described above as occurring in *Ascobolus*, agrees in all essential details with it.

There are certain species of *Peziza* the mycele of which forms conids, and the unripe fructification is represented by a resting *sclerote*. This has been observed in *P. Fuckeliana*. In it the conids are formed on the mycele prior to the sclerotes, and reproduce the mycele. No sexual process has been observed in connection with the formation of the sclerotes, which consist of a dense mass of hyphæ enclosed by a black rind or cortex. If the sclerote germinates shortly after its formation, the result is a mycele which bears conids again; but if germination is delayed for a month or two, a bason-shaped hymene is formed, on which asci containing ascospores arise. This form of fructification is that commonly known as *Peziza Fuckeliana*. Many species of *Peziza* have a distinct form, known as the "botrytis" form, reproduced by conids only; these were long believed to be distinct organisms allied to *Peronospora*.

In *Peziza* and the allied genera the whole fructification is bason-shaped, with the hymene on the inner surface of the bason; but in other cases, as *Morchella*, *Helvella*, *Geoglossum*, &c., it takes the form of clubs or stalked caps of considerable size, with the hymene on the outer surface.

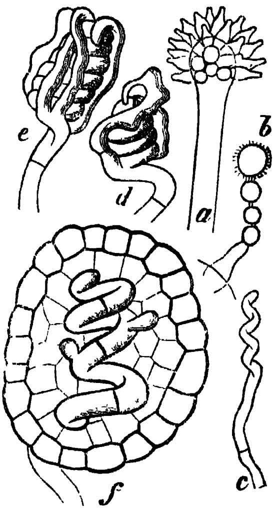
**Distribution, Qualities, &c.**—The smaller Discomycetes are parasitic on leaves, &c., causing black, purple, or yellow spots; the larger species are saprophytic on moist earth. Among the latter are some esculent species, as *Morchella esculenta* (the morel), *Helvella*, &c. The "botrytis" form of a *Peziza*, formerly described as *Botrytis bassiana*, parasitic on the larva of the silkworm-moth, produces the fatal disease known as "muscardine." The sclerotes of other species are exceedingly injurious to clover and other plants.

SACCHAROMYCES (see p. 82) is now generally regarded as an extremely simple form of Ascomycetous Fungi.

ERYSIPHEÆ.—Fungi growing on living plants and dead organic bodies, and consisting of a mycele which spreads on the surface of the host and sends into it numerous *haustoria*; forming small globular fructifications with thin coverings, which enclose one or several asci springing from a carpogone.

**Structure and Life-history.**—The species of *Erysiphe* grow on the leaves and green stalks of Dicotyledons—more rarely on Monocotyledons. The mycele ramifies densely on the surface of the host, through the epiderm of which it sends down numerous organs of attachment known as *haustoria*, and is multiplied by conids borne in series at the end of unbranched conidiophores. In certain species the conids are the only form of reproductive organs known: while in many other species of *Erysiphe*, the sexually produced fructification is easily to be found, either adhering to the mycelial threads or free. Both conids and the sexually produced fructifications (peritheces) are borne on the same mycele. The carpogone is surrounded by numerous antherids, and fertilization takes place in the same way as in the Discomycetes. In some species the fertilized carpogone contains only one ascus of an ovoid shape, which encloses eight ascospores. In other species the carpogone contains several asci.

Fig. 24.



*Eurotium herbariorum.* *a*, extremity of conidiophore with sterigmas; *b*, sterigma with chain of conids, *c*, young carpogone; *d*, *e*, further development of the same; *f*, young fructification in section, ×300. (De Bary.)

*Eurotium* agrees in the essential details of its life-history with *Erisyphe*. The mycele is floccose, and may be found on the surface of the most varied dead organic bodies. First are formed conids in great abundance in clusters at the apex of the conidiophores, supported on basal cells known as *sterigmas*, and these reproduce the mycele so plentifully that this fact, when coupled with the easily satisfied requirements of the fungus in the matter of hosts, accounts for its exceedingly wide distribution. On the same mycele there arise afterwards the sexual organs. The carpogone is the end of a mycelial hypha closely coiled in the form of a corkscrew, and provided with several transverse septa, one to each turn of the screw. From the lowest turn there arise two tubes which grow up on the outside of the carpogone; one grows more rapidly than the other, and reaches the top of the carpogone, with which it conjugates. This is the antherid. Other cells then grow out from the bottom of both organs and envelop them. After fertilization the carpogone divides into several cells, and on their branches the asci, containing 8 spores, arise. These ascospores germinate, as in the other *Erysipheæ*, and produce a mycele which bears first conids, and again the sexually produced fructifications or peritheces.

**Distribution, Qualities, &c.**—Several species of Erysipheæ are extremely common parasites on leaves, &c., which they deform; *Erysiphe Tuckeri*, formerly known as "oidium," causes a disease of the grape; *Eurotium*

(*Aspergillus*) *glaucum* is one of the commonest moulds on decaying fruit, preserves, &c. Some species of *Aspergillus* (*Eurotium*) are undoubtedly pathogenous. *A. glaucus* appears to be intimately connected with the disease of the ear known as "otiomycosis."

TUBERACEÆ.—Fungi forming usually large subterraneous tuberous fructifications, possessing a thick wall (*peridium*) of pseudo-parenchyme, enclosing a dense mass of hyphæ, among which the ascogenous threads form asci surrounded by the sterile threads (*paraphyses*). The mycele is usually small in comparison with the fructification; conids are known only in a few cases.

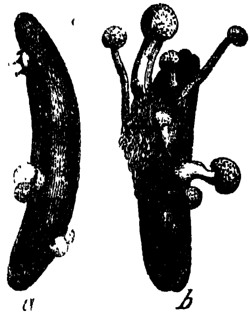
**Structure and Life-history.**—The mycele of *Penicillium glaucum* grows on almost all organic substances, and produces long chains of conids on erect conidiophores in such abundance as to account for their general presence in the air, and the appearance of the fungus on nearly every suitable and accessible host. It is only, however, in darkness that, as in the other Tuberaceæ, the fructifications are formed. The conids are not developed in darkness, and the formation of sexually produced fructifications in that condition is a further mark of the capacity of this fungus for distribution. The sexual organs very closely resemble those of *Eurotium*; but the development of the fructification after the fertilization of the ascogone differs from that of any other Ascomycete. The ascogone, after it has begun to germinate, is so hindered by the growth of the enveloping threads, that it rests for some time in a sclerotioid state. When germination is induced, however, by artificial means, the ascogenous threads force their way out and form asci, in each of which are 8 ascospores. These spores germinate and produce a mycele, which again bears conids. The sclerotes also, when kept so long that the ascogenous threads have lost the power of forming asci, germinate and form the usual conids.

**Distribution, Qualities, &c.**—*Penicillium glaucum* is the commonest of all moulds, on cheese, damp leather, &c. In the larger species, the very large perithece is usually underground; the esculent truffle is the underground fructification of *Tuber æstivum*.

PYRENOMYCETES.—Fungi growing usually on dead organic bodies and on living plants, and forming round or flask-shaped conceptacles (*peritheces*) with walls of pseudo-parenchyme, and containing long club-shaped asci, each of which produces (as a rule) 8 spores. The perithece is in some cases open from the first, but in others an opening is ultimately formed in the neck of the flask, through which the spores are emitted. When the ascospores germinate, they produce a mycele on which are formed *conids*, *stylospores* (in *pycnids*), and *pollinoids* (in *antherids*). In many species one or more of these organs are wanting, and in many others one or more of these are present and the peritheces wanting.

**Structure, &c.**—In a number of species the peritheces arise on a very fine mycele, singly or in groups, and in such cases it seems to be probable that they are the result of a sexual process. In other cases, however (as in *Xylaria*), the peritheces are formed on large club- or bason-shaped *stromas*, consisting of dense masses of hyphæ. It is uncertain whether the stroma is merely a receptacle, or whether there takes place in it a sexual process which gives rise to the peritheces. The conids are formed not only on the mycele, but also on the stroma or even (as in *Penicillium*) on the wall of the perithece. Sometimes conids and stylospores of two different forms occur in the same species.

Fig. 25.



*Claviceps purpurea.*
*a*. Young sclerote of Ergot.
*b*. The same further developed

**Distribution, Qualities, &c.**—The very numerous species of *Sphæria* are commonly parasitic fungi on leaves, forming red and brown spots &c. The medicinal "ergot" of rye and other grasses is the sclerote of *Claviceps purpurea*. Some species are also parasitic on insects, causing fatal diseases.

LICHENS (figs. 26 & 27).—Fungi consisting of a thallus of densely interwoven hyphæ, sometimes forming a pseudo-parenchyme, deriving their nourishment from minute Algæ (formerly called *gonids*) imbedded in the thallus, and forming regular organs of fructification, either *peritheces* or *apotheces*, containing asci, in some cases known to be the result of a sexual process. There are formed also on the thallus *antherids* containing *pollinoids*, the male organs, which have been proved in certain cases to fertilize the female organ or *carpogone* by means of a *trichogyne*; and occasionally *pycnids* containing *stylospores*.

**Structure and Life-history.**—The compound nature of Lichens has been completely established by the researches of Schwendener, Stahl, and others, in some species, and this is inferentially extended to the whole group. Each plant is a colony, consisting of a large number of algæ, belonging to the Protococcaceæ, Chroococcaceæ, Chroolepideæ, Nostocaceæ, Scytonemaceæ, and other groups, and constituting the so-called *gonidial layer*, closely invested by the hyphæ of an ascomycetous fungus (rarely belonging to any other group); the two organisms being mutually dependent on one another in the mode of existence known as *symbiosis*. Not only has this compound nature of Lichens been determined analytically, but they have in some cases also been constructed synthetically by causing the spores of the fungus to germinate in contact with the alga.

The process of sexual reproduction has been observed in the *Collemaceæ*. In this subdivision the minute *pollinoids* are formed within

closed receptacles, the *antherids*, and, unendowed with the power of motion, reach the female organs by the conduction of water (rain, &c.). The female organ or *carpogone* is composed of two parts:—a straight portion or *trichogyne*, and an *ascogone* in the form of coils, composed of several cells which, when fertilized, give rise to the carpospernis. The point of the trichogyne is protruded through the surface of the thallus, in which the rest of the organ is imbedded, and, the pollinoids coming in contact with it, the contents become amalgamated. The first result of the fertilization is seen in the increasing size of the cells of the ascogone, and also in the formation of transverse septa. *Paraphyses* or barren filaments then spring from the primitive coil of the ascogone, and increase in number with the formation of the hymene, on which ultimately the asci arise from the ascogenous filaments. The production of ascospores by the asci terminates the generation.

In addition to the ordinary gonids, a smaller form, called the *hymenial gonids*, occurs in the empty spaces of the apothece of many Lichens. They are the offspring of the true gonids by division, and are carried up in the hymene by the growth of the hyphæ. They are cast out of the apothece along with the spores, and the spores on germinating envelope with their germinating filaments the hymenial gonids, which increase in size and become the thallus-gonids of the new lichen. The gonids reproduce themselves exactly like the free individual Algæ of the same species or genus. Groups of gonidial cells, surrounded by a weft of hyphæ, which are pushed out from the thallus, and develop by division into a new lichen-thallus, are known as *soredes*.

Fig. 26.

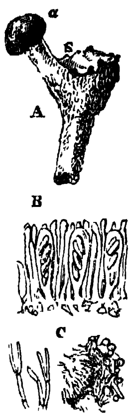



Fig. 27.

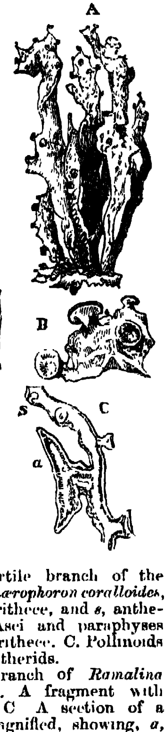



Fig. 26. A. Fertile branch of the thallus of *Sphærophoron coralloides*, with *a*, a perithece, and *s*, antherids. B. Asci and paraphyses from the perithece. C. Pollinoids from the antherids.

Fig. 27. A. Branch of *Ramalina fraxinea*. B. A fragment with apothecces. C A section of a fragment magnified, showing, *a*, apothece, and *s*, antherids.

**Distribution, &c.**—Lichens grow mostly in exposed situations, such as on rocks, walls, trees, &c. in all parts of the globe. They form a very large proportion of the entire vegetation in the higher regions of mountains and in polar latitudes. The thallus has usually a dry, dead-looking aspect (though sometimes soft and pulpy), and is of a foliaceous or scaly and crustaceous form. It varies much in size.

**Qualities and Uses.**—Many Lichens are very nutritious; a number of them yield valuable dyes; some are medicinal, others aromatic. Among the more important nutritious kinds are:—*Cladonia rangiferina*, Rein-

deer Moss; *Cetraria islandica*, Iceland Moss, and *C. nivalis*; *Umbilicaria* (various species), constituting "*Tripe-de-roche*" of the North-American hunters; *Lecanora esculenta* (Tartary) and *L. affinis*, *Sticta pulmonaria*, &c. From *Lecanora tartarea*, the purple dye called cudbear is obtained; *Parmelia parietina*, common on walls and roofs, gives a yellow colour; *Roccella tinctoria* (Mediterranean and Cape-Verd Islands, &c.), *R. fuciformis* (Madeira, Angola, Madagascar, S. America), and *R. hypomecha* yield the dyeing material orchil or orchel; litmus being obtained from these and other species of *Roccella*. Some species contain a considerable quantity of oxalate of lime in the form of crystals.

The genus GYMNOASCUS is an assemblage of small and very simple Ascomycetous Fungi growing on dung. Its mycele gives rise to numerous sexual organs, which, up to the time of fertilization, are (male and female) exactly alike. After fertilization the carpogone divides into a series of cells, from which there grow out short branched cells, on which the asci containing 8 spores are borne in abundance. The fructification is quite destitute of a covering.

## Series 2. BASIDIOMYCETES.

Fungi growing on dead organic matter and stumps of trees, and consisting of hyphæ interwoven, so as to form a fleshy, gelatinous, or firm thallus, the receptacle of the *hymene*. Hymene bearing spores usually arranged in fours, and known as *basidiospores*, at the apex of erect *basids*; either on the external surface of the receptacle, *gymnocarpous*, or lining cavities within it, *angiocarpous*. Sexual organs unknown. Mycele composed of septated hyphæ.

Since no sexual organs have yet been detected with certainty in the Basidiomycetes, their systematic position can only be assigned conjecturally. They are divided into the Orders Tremellineæ, Hymenomycetes, and Gasteromycetes, as follows:—

TREMELLINEÆ.—Fungi growing on stumps of trees and on the ground, of a gelatinous consistency, with sometimes a denser "nucleus," often cup-shaped. Hymene bearing two distinct kinds of basids in different genera. Spores kidney-shaped, in some cases divided, and in others not.

**Structure and Life-history.**—In the genus *Tremella* the basids are at first subglobular or quite spherical, and divided nearly to the base into four equal parts. These segments either remain united or become divergent from each other, while they grow out to the margin of the fungus in the form of long hyphæ, and produce there generally undivided and kidney-shaped spores. In *Dacrymyces* and *Guepinia* the basids are at first club-shaped, but subsequently grow out in the form of two thick diverging arms, on each of which is produced one kidney-shaped spore.

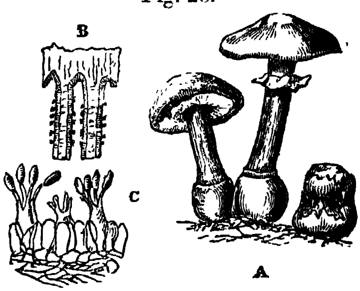
Under certain conditions the germinating hyphæ produce secondary spores or *sporids*, from which the ordinary mycele springs. The ordinary spores reproduce the plant directly. The consistence of these plants is very gelatinous, and they collapse on drying. If, however, they are placed in water, they very soon absorb it, and become again distended to their former size.

EXOBASIDIUM is a genus with extremely simple fructification, in which the basid bears directly a hymene consisting of closely-packed basids, each bearing four spores.

HYMENOMYCETES.—Mycele floccose, giving rise to a superficial hymene on which are produced erect basids bearing at the apex slightly stalked or sessile spores, usually in fours. The receptacle consists of hyphæ, usually densely packed into a pseudo-parenchymatous structure. It is mostly fleshy in texture, but sometimes very hard, or occasionally gelatinous.

**Structure and Life-history.**—The usual form of the "receptacle" of hymenomycetous fungi is that of a cap-shaped *pileus* raised upon a stalk or *stipe*, and bearing on the under surface *lamellæ* or gills (*Agaricini*), *pores* (*Polyporeæ*), or *teeth* (*Hydneæ*), on the surfaces of which are situated the basids, which bear the spores (fig. 28). The spores are the only propagative organs, and, so far as is yet known, are non-sexual in their origin. On germinating, they give rise directly to a new mycele, which bears again the spore-producing plant. Attempts have been made at different times to discover the existence of a sexual agency in the production of these spores, but as yet unsuccessfully. Among the basids are seen other cells of similar shape and usually larger size, called *cystids*, which are probably only barren basids. The mycele is entirely, or nearly so, underground.

Fig. 28.




The Mushroom (*Agaricus campestris*):—A. Receptacles, showing the expansion from the volva, and the veil tearing away and leaving the annulus. B. Section of lamellæ, magnified 50 diameters. C. Basids and spores from ditto, magn. 400 diam.

The Hymenomycetes are made up of the following Suborders:—

1. AGARICINI.—Hymene always inferior, and spread over the surface of *lamellæ* or "gills" which radiate from the stem; they may be either simple or branched, and attached to or distinct from the stem. The spores vary in colour; but one colour is constant as a rule to a genus or

subgenus. The stipe is sometimes cartilaginous and sometimes fleshy. On the stipe in some genera and subgenera is a ring or *annulus*, which is all that remains of a veil or covering (*velum partiale*) which, in an early stage, united that part of the stem with the outer edge of the cap or pileus, but was ruptured on the expansion of the latter. In certain subgenera of *Agaricus* the whole fungus is enclosed at first in a *volva* (universal volva), which on bursting falls away and is independent of the cuticle on the upper surface of the pileus, but remains attached to the base of the stipe. Sometimes both forms of veil are found together. The stipe is not always central, but is sometimes eccentric or even lateral.

2. POLYPOREÆ.—Hymene spread over the cavity of *tubes* or *pores*; either inferior or superior. The texture of the plant is, as a rule, more cartilaginous and woody than that of the *Agaricini*. *Boletus* has the habit of an Agaric, and usually its central stem and texture. The hymene is distinct from the hymenophore, from which the tubes are easily separated. *Polyporus*, on the other hand, differs from the *Agaricini* in habit, the stem when present being usually lateral, and the texture of the whole often very woody. The hymenophore is not easily separated from the pores. In the resupinate forms the pores open upwards, and the habit of the fungus is crust-like. The species of this genus grow, as a rule, on stumps of trees and other woody substances.

3. HYDNEÆ.—Hymene wholly or partly inferior, and spread over *teeth* or *spines*, which are soft, usually subulate, and distinct at the base. Some of the species have the form of a stalked pileus with the teeth on the under surface (*Hydnum*), while others resemble the resupinate forms of *Polyporus*.

4. AURICULARIEÆ.—Hymene confluent with the hymenophore. The habit is generally the same as in *Polyporus*.

5. CLAVARIEÆ.—Hymene distinct from the hymenophore, reaching to the apex of the plant, which is sometimes club-shaped, and sometimes in the form of spines usually growing together at the base. The surface is at first smooth, but becomes wrinkled afterwards. The plants are never encrusting nor leathery, but are usually at first gelatinous and afterwards horny.

**Distribution, Uses, &c.**—The Hymenomycetes are the largest and most familiar of the Fungi, growing everywhere as saprophytes on humus, dead stumps, decaying leaves, &c. Owing to the large quantity of nitrogenous constituents which they contain, many species are extremely nutritious articles of food. Among the most common esculent species may be mentioned *Agaricus campestris* (mushroom), *A. arvensis* (horse mushroom), *A. prunulus*, *A. ostreatus*, *Cantharellus cibarius* (chantarelle), *Marasmius oreades* (fairy-ring champignon), *Boletus edulis*, *Fistulina hepatica*, *Hydnum repandum*, and others. Other species are distinctly poisonous. *Polyporus fomentarius* yields the "amadou" of commerce, used for tinder. The mycele of several species of Agaricini and Polyporeæ are excessively destructive to forest-trees, causing dry rot. The phenomenon of phos-

phorescence is displayed by several Hymenomycetous Fungi when in a state of decay, sometimes by the pileus, more often by the structures formerly known as "rhizomorphs," the long flocculent persistent mycele of several species of *Agaricus*. In some Agaricini, as *Lactarius*, some of the hyphæ are transformed into laticiferous tubes, from which a copious latex flows out when injured.

GASTEROMYCETES.—Fungi forming roundish angiocarpous receptacles consisting of an outer layer or *peridium* enclosing a tissue, the "nucleus" or *glebe*, consisting of a number of chambers, on the walls of which is the hymenial layer, bearing the basids. The spores are borne at the apices of basids, one basid often producing as many as eight spores. They are liberated either by the simple bursting of the peridium, or by the development of particular masses of tissue.

**Structure and Life-history.**—In *Phallus* the peridium resembles the universal volva of some Agarics in the way in which it envelopes the internal part of the receptacle, and also in its manner of bursting. Within the volva is a gelatinous stratum, and within that again the hymene, which is very deliquescent and covered by an inner peridium. On the bursting of the peridium (or volva) the hymene is elevated in a sort of pileus by a stalk, as in the volvate Agaricini. In *Clathrus* the receptacle forms a globular network. In *Battarea* there is also present a universal volva, and the hymene is similarly elevated; but in *Lycoperdon*, *Hymenogaster*, *Nidularia*, &c., the bursting of the peridium sets free the spores without any such elevation, the hymene remaining in the interior. The spores reproduce the mycele, on which the same plant grows again without any intermediate stage as far as is known.

**Distribution, Uses, &c.**—There are a very large number of species of Gasteromycetes, varying in size from minute parasitic fungi to the large "puff-balls." *Lycoperdon giganteum*, the giant puff-ball, is esculent when young; the very numerous spores are used as a styptic. *Phallus impudicus*, the "stink-horn," grows with extraordinary rapidity, giving off a disgusting odour.

## Series 3. ÆCIDIOMYCETES (Hypodermiæ).

Fungi parasitic on living plants, and consisting of a mycele of interwoven hyphæ bearing non-sexual organs of propagation (spores) either in definite or irregular receptacles. The only sexual mode of reproduction known is the conjugation of spore-like *gametes*.

The Æcidiomycetes display the most remarkable illustration of "pleiomorphism" or alternation of generations, in the Vegetable Kingdom; but their position is provisional only. They consist of the two following

Orders (Uredineæ and Ustilagineæ); but as the mode of reproduction in the two Orders presents striking differences, it is probable that the affinity between them is not very close.

UREDINEÆ.—Hyphæ woven into definite fertile "receptacles," first situated beneath the surface of the affected part of the host, but at length bursting out. The propagative organs are non-sexual, and take three consecutive forms, arranged so as to form a cycle of generations on two different host-plants. Sexual organs unknown or obscure.

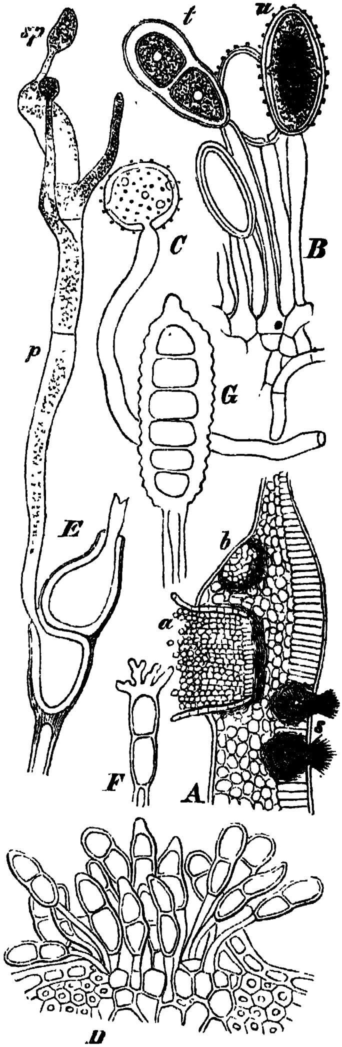
Teleutospores.
|
Æcidiospores accompanied by antherids.
|
Uredospores, and later, on the same mycele, teleutospores again.

**Structure and Life-history.**—The life-cycle of these parasites begins with the germination of the *teleutospores*—thick-walled spores situated at the end of filiform *basids*, either singly or in pairs. The germination takes place in spring, and consists in the emission of a germinating filament, which rapidly forms a *promycele* bearing three or four *sporids*. These sporids also soon push out germinating filaments, which, if on a suitable host-plant, penetrate the epidermal cells and form a mycele within the parenchyme. After a few days this mycele begins to form a new fructification under the epiderm of the host-plant, which eventually breaks out under the forms of the *æcidia* and their constant companions the *antherids*. The latter appear first, and round them, or irregularly among them, are the æcidia. The antherids are in shape small narrow-necked sacs of the same colour as the æcidia. In them are found minute bodies, called *pollinoids*, which are believed to be male organs which have lost their function, no female organs having as yet been found. The æcidia consist of round or oval receptacles, which afterwards become bason-shaped, the walls being composed of pseudo-parenchyme (short polyhedral closely fitting mycelial cells). At the base of this body is the hymene—a circular layer of short cylindrical club-shaped upright basids, each of which bears a series of spores in regular order, one above the other, of a round polyhedral form, and filled with protoplasm coloured red or yellow by oil. On the bursting of the enclosing peridium of pseudo-parenchyme the spores are liberated in a state capable of germination, which takes place in the form of short crooked germinating filaments that penetrate through the stomates of the next host-plant, and form rapidly a new mycele in the intercellular spaces. Again, after a few days, this mycele forms a new fructification—the *uredo*, which is at first of the shape of a flat circular cushion lying immediately under the epiderm of the affected part. On it arise filiform basids, each of which bears a round or oval spore, the *uredospores*, which during their formation break through the epiderm. These germinate rapidly and reproduce themselves constantly, and to this quality is the rapid and extensive spreading of these parasites to be attributed.

The same mycele which produces the uredo- afterwards forms the teleutospores, from which we started. The teleutospores hibernate and germinate again in spring, and so every year the parasite passes through the same cycle of generations.

**Distribution, Qualities, &c.**—The host-plants affected by the same species of Uredineæ are usually of two very different kinds. The teleutospores and uredospores affect chiefly the Gramineæ, and prove very destructive to that useful order of plants. The æcidiospores are not so much confined to one order, but affect a great variety of plants, to which they are by no means so destructive as the teleutospores and uredospores are to the Gramineæ. Until recently the different generations of these Fungi were taken to represent different genera, and even now they are so described by many mycologists. The æcidiospores represent the genus "*Æcidium*," the uredospores "*Uredo*," and the teleutospores "*Puccinia*" and "*Uromyces*." Each generation of each species has its peculiar host-plant, and of a not inconsiderable number there are only known one or two generations—the *Æcidium* only in some cases, and the *Uredo* and *Puccinia* only in others. The diseases on trees known as "witch-broom" are caused by the mycele of fungi belonging to this order. The "rust" of wheat is caused by a fungus known in one stage as *Æcidium Berberidis*, parasitic on the barberry, and in the other as *Puccinia graminis*, parasitic on wheat and other grasses.

Fig. 29.




*A*. Section of *Berberis*-leaf with æcidia, *a*, *b*, on the lower, and antherids, *s*, on the upper surface among the palisade-cells, slightly diagrammatic and enlarged. *B*. Teleutospores: *u*, simple, *t*, divided, ×390. *C*. Germinating teleutospore, ×390. *D*. Puccinia-(or teleuto-) spores on leaf of grass. *E*. Germinating teleutospore: *p*, promycele; *sp*, sporids, × 400. *A*, *B*, *D*, *E*, *Puccinia graminis*; *C*, *P. straminis*. *F*. Teleutospore of *P. coronata*, × 300; *G*. Teleutospore of *Phragmidium incrassatum*. *B* to *D* after De Bary, *E* after Tulasne.

USTILAGINEÆ.—Hyphæ interwoven, and bearing non-sexual spores irregularly. *Sporids* sooty-coloured, the result of the conjugation of *gametes*, sexual cells to all appearance exactly alike, produced on a *promycele*, resulting from the germination of a resting-spore; these sporids, when they reach a suitable host-plant, germinate and form a mycele on which the spores are again directly formed.

**Structure and Life-history.**—When the spores, which correspond to the teleutospores of Uredineæ, germinate, a promycele is formed which bears sporid-like *gametes*; these conjugate in pairs, and the united pair either directly produces a new mycele or sporids which do so. This mycele then again bears resting-spores on a different host.

**Distribution, Qualities, &c.**—The Ustilagineæ are very injurious, especially to the Gramineæ. The sporids attack the axis of the germinating plants, in which they develop a mycele, which is carried up with the growing plant, and ultimately produces spores in the fruits, and causes their destruction. The power of producing successive sporids tends largely to cause the plentiful distribution of the order. The "smut" of cereals and other grasses is due to the attacks of fungi belonging to this Order.

## Subclass ii. **Oomycetes.**

In the Oomycetes we have a distinct mode of sexual reproduction, in the fertilization of *oospheres* contained in an *oogone* by motile *antherozoids*; the result being the production of an *oosperm*. The non-sexual organs of reproduction are motile *zoospores* or motionless *conids*. The fertilized oospheres produce either zoosporanges or conids or sporanges, and on the same plant, but a little later, oospheres again; the non-sexual bodies also reproduce both themselves and the sexual bodies a little later. The entire vegetative body or mycele consists of a single tubular much-branched but unseptated cell.

This Subclass consists of only two closely allied Series.

### Series 1. SAPROLEGNIACEÆ.

Fungi growing for the most part in water, and chiefly on the dead bodies of insects, and consisting of a mycele of long densely interwoven hyphæ, which bears both sexual organs—*antherids* and *oogones*—and non-sexual *zoosporanges*. The contents of the oogones, when fertilized by the antherids, are called *oosperms*, and on germinating produce a mycele which bears first zoosporanges and later the sexual organs. The zoosporanges on

bursting produce *zoospores* which, after a short motile state, come to rest, germinate, and form a mycele which produces again zoosporanges, and later the sexual organs.

Oosperms

Zoosporanges | Oosperms

Zoosporanges | Oosperms. | Zoosporanges | Oosperms.

**Structure and Life-history.**—In the monœcious forms the antherids and oogones are produced beside each other on the same plant; but in the others, first antherids and then oogones. The oogones are usually situated at the end of short branches of the mycelial hyphæ, and are very rarely interstitial. In the monœcious forms they are globular cells, rich in protoplasm, which is at first equally distributed. Subsequently the protoplasm gradually separates into several oospheres, which become rounded off and float together in a watery fluid within the oogone, each bounded by a smooth membrane which does not consist of cellulose. In *Pythium*, *Aphanomyces*, and several species of *Saprolegnia*, the whole of the protoplasm within the oogone contracts into a single oosphere, which, floating in the watery fluid, takes up its position in the middle of the oogone. During the formation of the oogone the antherids grow out from the same branch of the mycele or from neighbouring hyphæ in the form of thin cylindrical crooked twigs, often wound round the stalk of the oogone. The upper ends adhere to the wall of the oogone, swell slightly, and become bounded at the base by a septum. At the time of the formation of the *oospheres* within the oogone, each antherid pushes through the wall one or more tubes, which open at the points and discharge their contents, minute motile antherozoids scarcely $\frac{1}{500}$ millim. in size. A single antherid will sometimes fertilize several oogones. The oospheres, after being fertilized, acquire a cellulose membrane, and become oosperms; but the actual process of impregnation is still involved in considerable doubt. According to Pringsheim, the fertilizing bodies are not antherozoids, but "spermamœbæ," peculiar bodies endowed with an amœboid motion, which are produced within the antherid, and enter the oogone.

In the diœcious forms the oogones and oospheres are formed as in the monœcious species. The antherids, on the other hand, are formed in thick bladder-like protuberances which arise at fixed times on the mycele, and are divided by transverse walls into a series of cylindrical cells, each of which represents an antherid. In *Saprolegnia dioica* the whole of the protoplasm of the antherid breaks up into numerous minute antherozoids, which are discharged from an opening in a narrow protuberance of the wall of the antherid. In *Achlya dioica* the contents of the cylindrical antherid are divided into a number of portions (of about the size of the zoospores of the species). These in their turn break up into small antherozoids, which emerge first from their special mother-cells and then from the antherid, in the same way as in *Saprolegnia dioica*. The antherozoids of both species have a single long cilium. In some species of *Achlya* the antherozoids are destitute of a vibratile

cilium. The ripe oosperms of *Saprolegnia* (so far as they are yet known) possess a membrane consisting of two coats, and produce germinating filaments after a period of rest. They have also been known to produce zoospores after a short period of rest. Parthenogenesis, or the production of fertile oosperms without the action of antherozoids, occurs in *Achlya* and *Saprolegnia.*

**Affinities, Distribution, Qualities, &c.**—The Saprolegniaceæ are nearly allied to some of the Algæ belonging to the Subclass Oophyceæ, such as *Vaucheria,* and it is uncertain whether some of its genera are not rather Algæ than Fungi. In other respects they approach the Mucorini. They are common parasites on living and dead animals. *Saprolegnia ferax* is extremely destructive to salmon.

## Series 2. PERONOSPORACEÆ.

Fungi parasitic on living Phanerogams, and consisting of a mycele of densely ramifying hyphæ, which bears both sexual organs, *antherids* and *oogones,* and non-sexual *conids.* The mycele which ramifies within the host-plant first bears the conids either singly on branching tree-like, or in a vertical series on club-shaped *conidiophores,* which appear upon the surface of the affected part of the host-plant. The conids are either simple spores, which reproduce the mycele by emitting germinating filaments directly, or zoosporanges, the germinating zoospores of which give rise to a new mycele. This new mycele in both cases produces conids again, and later the sexual organs. The germinating oosperms also produce a mycele, which bears both conids and afterwards the sexual organs.

Oosperms

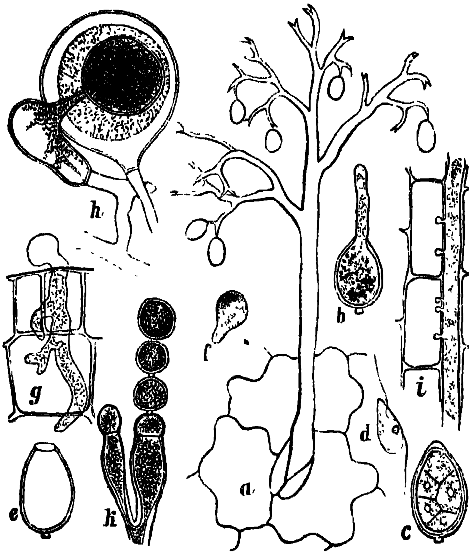
Conids — Oosperms

Conids — Oosperms — Conids — Oosperms.

**Structure and Life-history.**—The reproduction of the Peronosporaceæ strongly resembles that of the monœcious Saprolegniaceæ. The oogones arise at the end of short branches of the mycele in the intercellular spaces of living Phanerogams, and resemble those of the monœcious Saprolegniaceæ both in form and in being rarely situated interstitially on the mycele. The antherid grows either on the same branch or a neighbouring one, and is also similar in form to those of the monœcious forms of the preceding Series. The process of fertilization is also similar, except that the protoplasm within the oogone constantly contracts into a single oosphere. The oosperms germinate after a long period of rest, usually lasting throughout the winter. Two forms of germination have been observed. In *Cystopus candidus* the oosperm bursts and produces the

same number of zoospores as the zoosporanges. In *Peronospora Valerianellæ* the oosperms produce each a germinating filament or *promycele*, which, by repeated ramification, forms a new mycele. The conids

Fig. 30.




*a*, *Peronospora grisea*: conidiophore protruding through a stomate, × 240. *b*–*g*, *Phytophthora infestans*, × 400 (De Bary): *b*, conid germinating; *c*, formation of zoospores in conid; *d*, zoospore, *e*, empty conid; *f*, germinating zoospore; *g*, a similar spore germinating in the tissues of a potato-stem. *h*, *Peronospora Alsinearum*, antherid and oogone, × 350 (De Bary). *i*, *k*, *Cystopus candidus*. *i*, mycele with suckers or haustoria in the cortical tissue of *Capsella bursa-pastoris*, ×200; *k*, conids of the same, ×250.

also either produce germinating filaments or zoospores. The mycele of *Cystopus* is provided with numerous organs called *haustoria*, which, in the shape of small bladders, penetrate the cell-walls of the host-plant, and extract the nourishment for the use of the fungus.

**Affinities, Distribution, Qualities, &c.**—The Peronosporaceæ are very nearly allied to the Saprolegniaceæ, and are parasitic on land-plants; species of *Cystopus* and *Peronospora* are extremely destructive to wild plants. *Phytophthora infestans* is the potato-blight. The zoospores penetrate into the mesophyll of the leaves through the stomates, especially in wet weather, and grow rapidly, the absorption of nutriment from the leaves by the mycele rapidly causing decay of the haulm and tubers.

## Subclass iii. **Zygomycetes.**

As in the Oomycetes, the mycele consists of a single branched tubular cell, which is septated only when about to produce organs of reproduction. Sexual reproduction (*conjugation*) takes place by the formation of two equal club-shaped branches of the mycele, the extremities of which, each being cut off by a septum, come into contact, when the cell-walls disappear at the point of contact, and the protoplasm within the two septa coalesces into a *zygosperm*, which invests itself with a cell-wall, and has the power of germinating. The non-sexual reproductive cells are, in the Mucorini, motionless spores enclosed in a *sporange*.

The Zygomycetes include only one well-marked group; but it is probable that the Ustilagineæ ought properly to be included under this Subclass.

### Series 1. Mucorini.

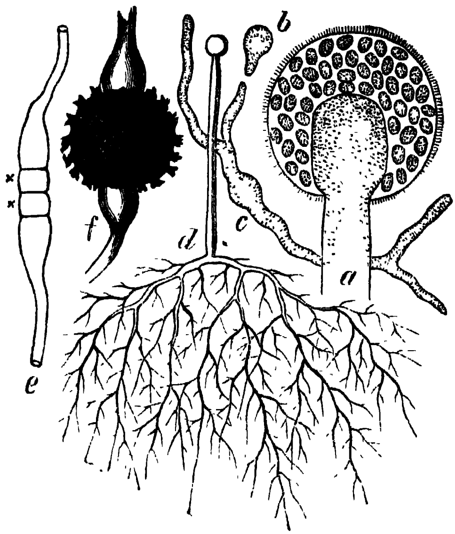
Fungi growing on plants or on the surface of organic solutions, and consisting of a densely branching unseptated mycele, bearing both sexual organs and non-sexual *sporanges*. The result of the union of the conjugating sexual bodies is called a *zygosperm*. The zygosperms have a double cellulose-coat, the outer one being commonly covered with spines.

Zygosperm
- Sporanges
  - Sporanges
  - Zygosperms.
- Zygosperms
  - Sporanges
  - Zygosperms.

**Structure and Life-history.**—The sporanges are similar in function and in some degree in structure to the zoosporanges and conids of the Saprolegniaceæ and Peronosporaceæ. They appear at the end of *sporangiophores*, which, up to the time of fructification, are, like the mycele, without septa. A prolongation of the sporangiophore passes through the sporange, forming the *columel*, and round this the rest of the protoplasm is converted into spores by free cell-formation. The spores germinate by means of germinating filaments, and form a mycele by repeated ramification. Interior non-sexual spores, *chlamydospores*, are sometimes formed by concentration of the protoplasm within the mycele. The following is the nature of the sexual organs in *Rhizopus nigricans*. The conjugating cells are elongated stout irregularly branching and interwoven tubes. Where two meet each pushes against the other a protuberance, at first cylindrical and of equal thickness with itself. They remain closely attached, and soon grow to a considerable size, chiefly in thickness. At the end of each a separate cell is formed by the growth of a partition.

These two cells are usually of unequal size—one as long as it is broad, and the other only half as long as its breadth. The original membrane which separated them now becomes perforated in the middle, and soon vanishes altogether; the two conjugating cells then unite and form a *zygosperm,* which increases rapidly in size, and usually attains a diameter of over $\frac{1}{5}$ millim. It is, as a rule, drum-shaped, the ends smooth, and the free surface clothed with wart-like protuberances. The contents

Fig. 31.




*Mucor Mucedo*: *a*, sporange in optical section, × 200; *b*, *c*, germinating spores, × 250; *d*, mycele with sporange, slightly magnified, diagrammatic; *c*, conjugating mycelial filaments, × 80, *f*, ripe zygosperm undetached, × 100. *e* and *f* after Brefeld.

are coarsely granular protoplasm, often accompanied by large drops of oil. The germination of the zygosperm, as observed in *Syzygites,* is by means of a germinating filament, which, by repeated dichotomous branching at the expense of the stored-up matter in the zygosperm, soon forms a new mycele bearing non-sexual sporanges. When sown in organic, and especially in saccharine solutions, *Mucor* assumes a totally different form, breaking up into a number of globular detached spores, closely resembling *Torula.*

**Affinities, Distribution, &c.**—The Mucorini present several very strong points of resemblance to the Peronosporaceæ. Several species, especially *Mucor Mucedo,* are extremely common moulds on fruits, bread, dung, &c. The aquatic form has the power of inciting fermentation.

The ENTOMOPHTHORACEÆ form a small group, apparently intermediate between the Saprolegnieæ and the Mucorini. To it belongs *Empusa muscæ*, which covers with a flocculent growth the bodies of flies decaying in water. The mode of conjugation is similar to that in the Mucorini.

PIPTOCEPHALIDEÆ are a small family of moulds, parasitic on other fungi, sometimes separated from the Mucorini. The mode of conjugation is the same. The conidiophores are much branched towards their summit, and bear *stylospores* not enclosed in a sporange.

CHYTRIDIACEÆ are a family of minute fungi, parasitic on or in other fungi, algæ, or flowering plants, the systematic position of which is uncertain. Their reproductive organs are very liable to be mistaken for those of their host. They produce zoospores; and conjugation of both motile and motionless cells is said to have been observed in them.

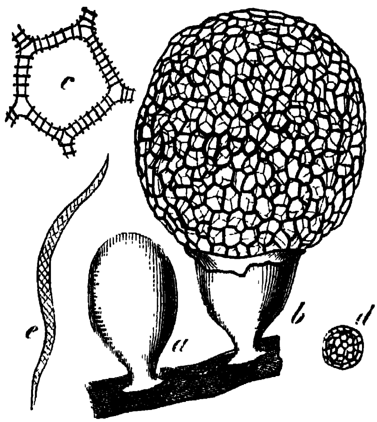
## Subclass iv. (?) **Myxomycetes.**

Naked motile masses of protoplasm, known as *plasmodes*, with a changing form. These masses, at the time of fructification, break up into separate parts known as *sporanges*. Within the sporanges are produced *spores* by free cell-formation, or on the surface by division. The contents of the spores at the time of germination break up into naked *zoospores*, provided with a nucleus, a vacuole, and long cilia, or into *amœboids*. These zoospores or amœbæ, known as *myxamœbæ*, flowing together in masses, give rise again to motile plasmodes.

**Structure and Life-history.**—The Myxomycetes present phenomena so entirely different from those occurring in other Thallophytes, that some regard them as more properly animal organisms, to which at least one stage of their existence shows the greatest similarity. The motile or plasmode stage resembles very strongly the motile *Amœbæ*; but the fructification is so little like the "encysting" of these animals, or any other process in animal life, and moreover is so fungal in its nature, that this proposition has not been generally accepted. The plasmode is of a slimy or creamy appearance, and contains a number of anastomosing net-like channels, along which there courses an ever-streaming current of protoplasmic matter, bearing such foreign bodies as spores of fungi, starch-granules, particles of colouring-matter of different natures, &c. These channels are not confined by a definite membrane, so that a constant changing of position and direction is permitted. By-and-by a state of rest is attained, and a capsule or sporange containing spores is formed, which reproduce the organism in a truly fungal manner. In addition to the spores, the sporange of many species contains a mass of delicate filaments known as the *capillitium*, round which there sometimes runs a spiral thickening band. In the simplest forms, as *Dictyostelium*, the spores are naked, or not enclosed in a sporange. The motion of the myxamœbæ, which contain a nucleus and vacuoles, is brought about by peculiar retractile processes known as *pseudopodes*.

**Distribution, Affinities, &c.**—The Myxomycetes are not uncommon in damp situations, on old stumps, &c. The plasmode of *Æthalium septicum*, known as "flowers of tan," forms yellow flocculent masses in tan-pits. From their very peculiar structure, their affinities are very doubtful. Not only their amœboid motion, by means of which they will creep great distances over the substratum, especially in the dark, but their mode of absorbing whatever nutrient substances come in their way, presents a close analogy to the lower forms of animal life. They are

Fig. 32.




*Arcyria incarnata*: *a*, closed, and *b*, dehiscent peridium, with the expanded capillitium, ×20, *c*, a portion of the capillitium, ×200, *d*, spore ×400. *e*, *Trichia clavata*, thread of capillitium, with spiral thickening.

regarded by some as belonging to the Zygomycetes, but the union of the "myxamœbæ," followed by the "encysting," or excretion of a cell-wall of cellulose, can hardly be regarded as a true process of conjugation similar to what takes place in that Subclass. The disease in cabbages known as "club-disease" is believed to be caused by the attacks of *Plasmodiophora*, a very simple Myxomycete.

## Class VI. *Protophytes*.

Under this Class are comprised all those simplest forms of vegetable life, whether containing chlorophyll or not, in which all the functions of life, both nutritive and vegetative, are performed by a single cell, which is always minute, and does not at any time divide to form sexual organs. A number of cells are frequently enclosed together in a common gelatinous envelope. When free

they are usually endowed with spontaneous motion of various kinds. Many of the Protophytes are in all probability stages in the cycle of development of more highly organized Algæ or Fungi. The Protophytes are divided into two Subclasses, according to the presence or absence of chlorophyll.

## Subclass i. **Protophyceæ** (Phycochromaceæ).

Protophytes either consisting of single cells living isolated and sometimes provided with vibratile cilia, or united together in mucilaginous masses, or of elongated filaments, sometimes divided by extremely delicate transverse septa, and endowed with a slow undulating motion. Chlorophyll either pure or coloured by a bluish pigment (*phycocyanin*). In our present state of knowledge any classification of the Protophyceæ must be regarded as provisional only. They may be conveniently divided into five Series, as follows:—

### Series 1. RIVULARIACEÆ.

Very slender moniliform filaments of roundish cells imbedded in jelly, running out at the extremity into a long hyaline hair, the basal cell being a much larger *heterocyst*. Propagation by spores.

**Structure and Life-history.**—Multiplication is effected by the cell next the basal heterocyst increasing in length, assuming a cylindrical form, and becoming invested with a firm membrane. When the whole of the rest of the colony perishes, these *resting-spores* only remain, and produce a new colony by cell-division.

**Distribution, &c.**—The Rivulariaceæ form soft greenish-blue lumps of jelly, which swim about in stagnant water, or grow attached to water-plants. They give the fetid odour and poisonous properties to stagnant water.

The SCYTONEMACEÆ are nearly allied to the Rivulariaceæ, forming branched filaments enclosed in thick gelatinous envelopes.

### Series 2. OSCILLATORIACEÆ.

Rigid cylindrical filaments enveloped in a gelatinous sheath, sometimes divided by very delicate transverse septa into disk-like cells, which readily separate and then become globular; somewhat curved, and endowed with a constant oscillating movement.

**Structure and Life-history.**—In the Oscillatoriaceæ there are no heterocysts, nor any propagation by means of special spores. Multiplication takes place by the detachment of portions of the filaments, which carry on an independent existence, and are then known in this and allied

families as *hormogones*. These hormogones usually consist of a string of several cells, which detaches itself from the rest of the filament, escapes from the common gelatinous sheath by a wriggling motion, and then develops into a new filament.

**Distribution.**—Common in running water.

## Series 3. NOSTOCACEÆ.

Moniliform curved filaments of cells imbedded in a copious jelly: the ordinary small cells replaced here and there by larger cells or *heterocysts*.

**Structure and Life-history.**—The function of the heterocysts is obscure. Multiplication takes place by the portions of the filaments between the heterocysts becoming detached, straightening themselves, escaping from the enveloping jelly, and the cells then dividing. The jelly-like colonies of *Nostoc commune* are not uncommon on the surface of moist ground, and are sometimes endophytic in the tissues of the higher plants.

## Series 4. PALMELLACEÆ (Protococcaceæ).

Green unicellular organisms, occurring in three stages:—(1) the *Protococcus*-form, primordial ciliated cells, swimming free in water; (2) the *encysted* condition, clothed with a cell-wall, also free; (3) the *Palmella*-condition, collected into colonies, which are invested in a common gelatinous envelope.

Fig. 33.

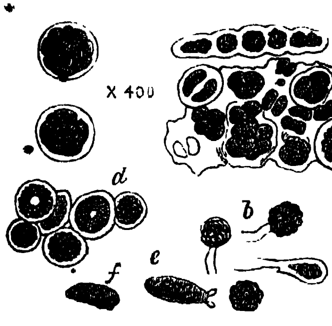



Fig. 34.

Fig. 33. *Protococcus viridis*:—*a*, group of cells, the upper with eight in a linear series, those to the left dividing; *b*, zoospores set free by the solution of the cell-wall; *c*, cell dividing into two zoospores; *d*, resting-cells; *e*, zoospore with the cilia cast off; *f*, zoospore.
Fig. 34. *Palmella nivalis*, or "red snow."

**Structure and Life-history.**—In the *Protococcus*-condition these organisms are indistinguishable from the zoospores of the higher Algæ.

In addition to chlorophyll they often contain a red pigment. In the encysted condition they multiply by bipartition, and in the *Palmella*-condition they also divide freely in two or three directions.

**Distribution, Properties, &c.**—Many organisms included in this family are probably connected genetically with more highly organized Algæ. *Protococcus viridis* is extremely common in rain-water pools &c. Some of them occasionally appear suddenly in vast quantity, colouring lakes green; or, as in the case of *Palmella nivalis* (fig. 34), giving rise to the phenomenon called "Red Snow." *Palmella cruenta* often forms large patches of substance like half-coagulated blood on damp stones and rocks. The Palmellaceæ are regarded by some as disintegrated cells of Confervaceæ.

### Series 5. CHROOCOCCACEÆ.

Roundish cells living either isolated or in colonies composed of a few cells, enveloped in an abundant colourless jelly; the cell-contents coloured blue-green or violet by the *phycocyanin* dissolved in the cell-sap.

**Structure, Distribution, &c.**—The Chroococcaceæ are probably the lowest forms of vegetable life. They are beautiful objects found in fresh water, usually living in colonies imbedded in a transparent jelly, and moving about freely. They are allied to the Palmellaceæ, but do not possess vibratile cilia, nor do they excrete a true cell-wall of cellulose, nor become aggregated into immotile palmella-colonies.

## Subclass ii. Protomycetes.

Unicellular protophytes not containing chlorophyll, and capable of living only in organic fluids, where they occasion fermentation or putrefaction; not endowed with cilia. Propagation by cell-division or free cell-formation. The Protomycetes are divided into two well-marked Series:—

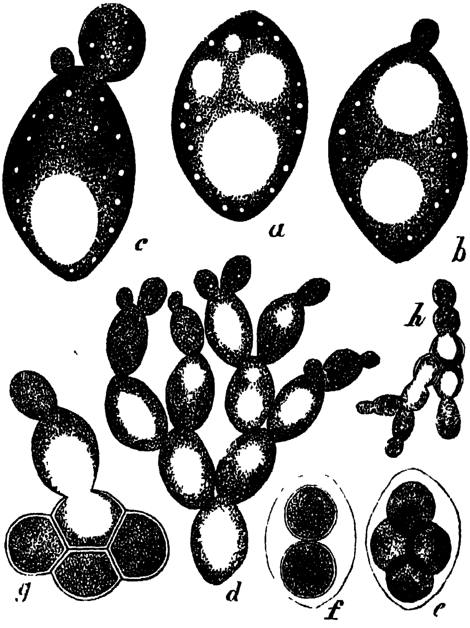
### Series 1. SACCHAROMYCETES.

Isolated cells, reproduced by cell-division (*gemmation*) or by the endogenous formation of spores by free cell-formation; causing fermentation in fluids containing carbohydrates.

**Structure and Life-history.**—The ordinary Yeast of beer consists of an immense number of minute nearly globular cells of *Saccharomyces cerevisiæ*, containing a vacuole; but it is doubtful whether they contain a nucleus. The ordinary mode of multiplication (when warmth is applied) is by a form of cell-division which has been called *gemmation* or *budding*. A protuberance appears at one point of the cell, which rapidly attains the size of the parent-cell, and then becomes separated by a septum and

detached. A second but rarer mode of multiplication is by the endogenous formation of *spores* by free cell-formation. The protoplasm of the cell divides usually into four portions, each of which surrounds itself by a cell-wall, and the daughter-cells are eventually set free by the dissolution of the wall of the parent-cell.

Fig. 35.




*Saccharomyces cerevisiæ* (yeast): *a*, isolated cell, with vacuole; *b*, cell commencing to bud *c*, *d*, further stages; *e*, yeast-cell producing endogenous spores; *f*, mother-cell with two complete daughter-cells; *g*, mother-cells, one in process of germination; *h*, further development. (*e*–*h* after Reess.) ×750.

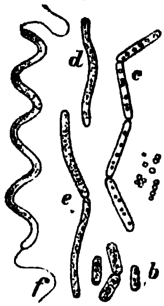
**Affinities, Properties, &c.**—According to Brefeld torula-cells are probably merely a stage of existence in the cycle of development of more highly developed fungi. Other writers regard the endogenous formation of spores in *Saccharomyces* as the simplest instance of the development of ascospores; and consider these organisms therefore as the lowest members of the Ascomycetes (see p. 61). All members of the family have the power of producing fermentation in saccharine fluids. The different species and genera which have been described may possibly be different forms of the same organism developing under different conditions. *Saccharomyces cerevisiæ* is the ordinary yeast of beer; *Mycoderma vini* and *aceti* (the so-called vinegar-plant) are regarded by some as the

organisms which cause the production of wine and vinegar respectively *Saccharomyces albicans* is the "thrush-fungus," which lives parasitically on the mucous membrane of the human digestive organs.

## Series 2. SCHIZOMYCETES (Bacteria).

Extremely minute unicellular organisms, growing in organic fluids, and occurring in the following forms or conditions:— (1) *Micrococcus*, globular; (2) *Bacterium*, short straight rods; (3) *Bacillus*, longer straight rods; (4) *Vibrio*, curved rods; (5) *Leptothrix*, straight filaments; (6) *Spirillum*, curved filaments; (7) *Zooglœa*, colonies of globular cells imbedded in mucilage. All except (1) and (7) endowed with rapid vibratory motions, multiplying by division only. Always accompanying putrefaction.

Fig. 36.




Various forms of Bacteria: *a*, *Micrococcus prodigiosus*; *b*, *Bacterium lineola*; *c*, *Bacillus ulna*, thread of four cells; *d*, *Vibrio rugula*; *e*, the same in process of division. *f*. *Spirillum volutans*. ×650. (After Cohn.)

**Structure and Life-history.**—In our present state of knowledge, it is impossible to arrange the various forms of Schizomycetes in genera and species. Recent researches of Zopf would seem to indicate that they may probably all be convertible one into another, and be merely different conditions of the same organism. *Bacterium Termo* appears to be remarkably sensitive to light. In the *bacillus*-condition, and occasionally also in other states, internal globular spores are formed and become detached.

The greatest practical importance attaches to the life-history of these unicellular organisms. The cells of which they consist are of various sizes and shapes, dividing by septation of their protoplasm, and sometimes by an endogenous formation of spores They are isolated, or associated, in the latter case often by mucous investment (zooglœa). Too much importance must not, however, be attributed to their forms, as all those described may be met with in the life-history of one and the same species when exposed to varying conditions, so that the forms are probably to be considered as stages in the development of species rather than as distinct organisms. Most of them are destitute of chlorophyll, and live upon organic matter like Fungi, requiring also a supply of oxygen; but others contain chlorophyll (*Bacterium viride*). Some, like *Bacillus amylobacter*, the agent in butyric fermentation, only live in an atmosphere in which oxygen has no place. Many are markedly influenced by light accumulating on the side of the vessel exposed to the light, others are motionless till they are subjected to the influence of the light, or rather of the yellow or red rays of the spectrum. Others, again, develop a colouring-matter, as in the case of the red substance which occasionally develops with great rapidity upon bread or milk. Some are phosphorescent, and are the cause of the luminosity of decaying fish, &c.

It has been proved by the researches of Pasteur and others that certain fermentative processes, such as the acetic, lactic, butyric, &c., the putrefaction of organic matters, the progress and course of certain diseases in animals and in mankind, are essentially connected with the presence and development of these organisms. If they are excluded or the conditions be unfavourable no change is effected; on the other hand, the changes in question are set up and the diseases produced when the bacterial germs are introduced by inoculation or otherwise. The germs may be artificially cultivated, and their mode of life thus made manifest. The part that bacteria play in the nutrition of higher plants is illustrated by the fact that certain bacteria in the soil have been proved to be the agents in the conversion of the insoluble nitrites into the soluble nitrates.

The butyric ferment is *Bacillus amylobacter*, which causes the decomposition of cellulose, starch, sugar, gums, glycerin, &c., breaking them up into butyric acid, carbon dioxide, hydrogen, &c. By reason of its action on cellulose it plays an important part in the digestion of vegetable substances in the Herbivora. Whether the acetic fermentation, which oxidizes alcohol and converts it into acetic acid, is due to the action of special Schizomycetes, or to organisms belonging to the Saccharomycetes, is still a doubtful point. Lactic fermentation is due to *Bacterium lactis*, which changes the sugar of milk into lactic acid.

As to the bacteria associated with various diseases, such as the *Bacillus anthracis*, the cause of charbon in animals, *Bacillus tuberculosis*, supposed to be the morbific agent in phthisis, and others found in various diseased conditions, *e. g.* in cholera, it is at present requisite to speak with caution, for it is very difficult to isolate the particular organism, and to establish beyond dispute what its action is, to prove that the effects which are observed are really due to no other cause, as, for instance, some soluble ferment, and that the bacteria are not consequences rather than causes, finding favourable conditions in the diseased state of the body. Nevertheless some cases seem to be fully established; and the practical importance of the discovery is shown by the fact that it is possible, by artificial cultivation, to diminish the infective power of the bacteria, and render their action on the system less violent. Hence the explanation of the good effects of vaccination, and the hopes that are engendered that further investigations in this direction may lead to similar means of diminishing the intensity of fevers and other zymotic diseases, and even of such diseases as hydrophobia. Thus *Bacillus anthracis* is said not to produce its endogenous spores in the blood of animals, but when cultivated artificially in chicken-broth it develops the spores. If carbolic acid in certain proportions be added to the broth at a certain temperature, the spores are not produced; but if the *Bacterium* taken from this source be afterwards cultivated in ordinary broth, the spores are produced and the *Bacterium* propagated, but in its attenuated form. The formation of spores in any case is not observed till the food on which the organism subsists is becoming exhausted; growth then ceases, and the plant enters upon its resting-stage. In this condition the spores are able to withstand great extremes of temperature wihout injury. The degree varies in different kinds, prolonged boiling in some cases being insufficient to destroy them. A temperature of 35° C. is that which is found most generally propitious, both to their segmentation and to the

formation of spores. By some observers the bacterial organisms found in diseased states are supposed to be themselves innocuous, but to act indirectly as carriers of the *materies morbi*, whatever it may be, and this is consistent with the fact that certain bacterial organisms may exist in healthy blood without injurious effect to man.

**Distribution, Properties, &c.**—The Schizomycetes occur in prodigious numbers in all organic solutions where decay is going on; they are always present in the air, and, in fact, everywhere where not artificially excluded. Whether they are merely accompaniments of putrescence, or whether they occasion it in somewhat the same way that the Saccharomycetes cause fermentation, is still in dispute; but there are very strong grounds for accepting the latter hypothesis. There seems little doubt that *Bacterium amylobacter* is capable of acting on starch in a manner analogous to diastase. Many more or less definite forms are invariable accompaniments of specific diseases of men and other animals; such as the distemper of cattle, "charbon," "anthrax," foot-rot, the cholera of fowls, and probably that of human beings, &c. The disease known as "favus," which attacks the head of man, is caused by *Achorion Schœnbeinii*; and the spores of *Trichophyton tonsurans* penetrate the hairs, rendering them brittle, making them fall off, and causing ringworm. Others are always present in the various secretions of the body, even in a healthy condition. *Sarcina* is always found in the stomach, and *Leptothrix buccalis* in the mouth. *Micrococcus prodigiosus* often causes mouldy bread to assume a red colour, spreading with great rapidity. The enormous importance of the subject from a pathological and surgical point of view has caused a great amount of attention to be paid to these organisms; but many points in their life-history still remain to be cleared up.

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